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#204 MAY 2022

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

THE GLORIES OF GALAXY SEASON

Discover 19 stunning targets beyond the Milky Way this spring

FIND EARTH'S SHADOW IN TWILIGHT SKIES

7 KEY FIGURES IN THE HUNT FOR DARK MATTER

RED MOON AT DAWN

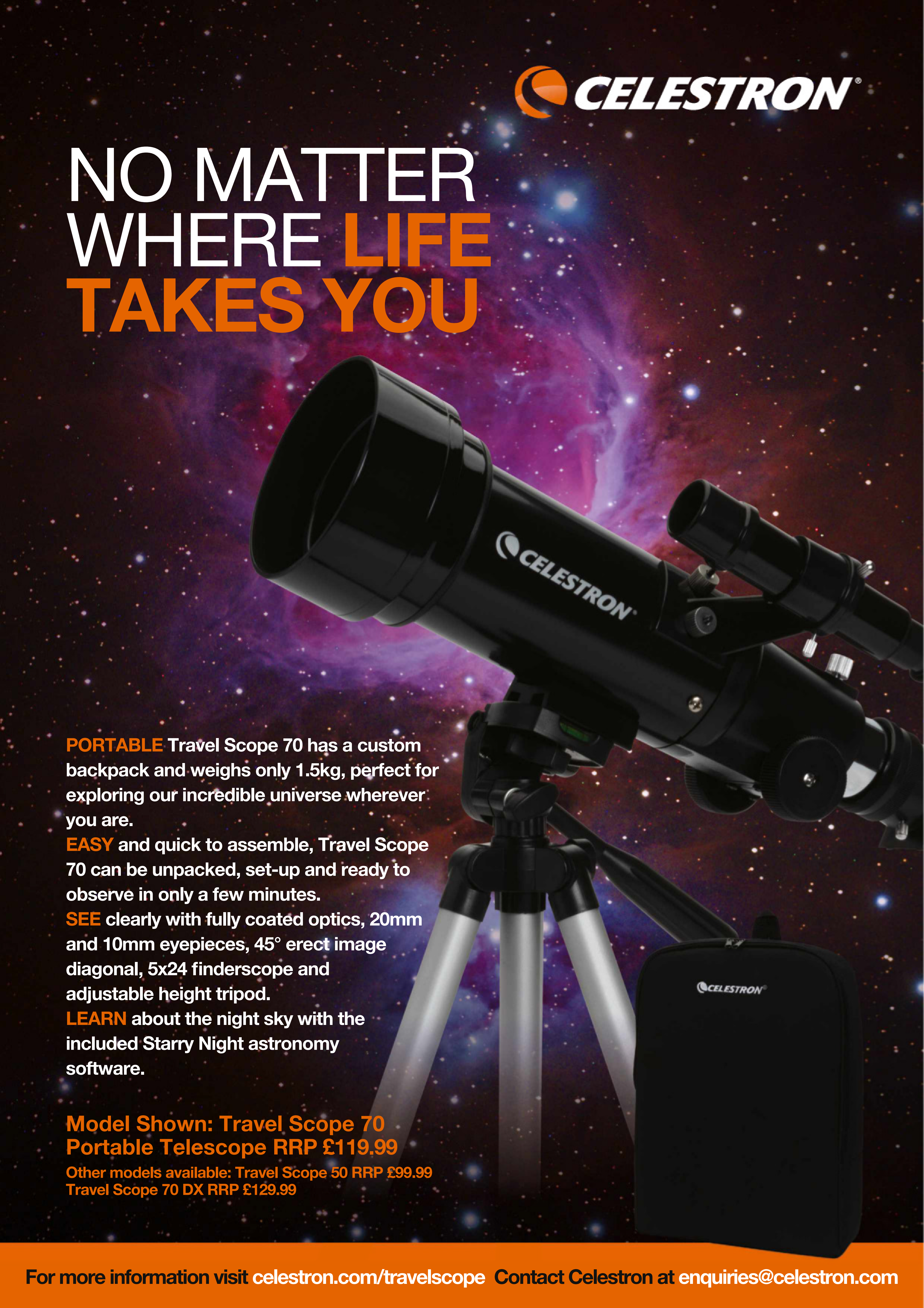
See this month's total lunar eclipse!

WHY EVERY IMAGER NEEDS TO KNOW ABOUT LAYERS

6 STUNNING TARGETS TO SEE WITH BINOCULARS

KNOW YOUR WAY AROUND THE CELESTIAL SPHERE

HOW PARTICLE PHYSICS & ASTRONOMY ARE RELATED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Welcome

Found all the Easter eggs? Go on a spring galaxy hunt

Spring skies mean one thing for stargazers, it's galaxy time. This is the season when the constellations that have the Milky Way running through them are conveniently out of the way when darkness falls; and when we're presented with a view out of our own Galaxy, many more are there waiting to be discovered. So join the hunt on **page 28**, where author and amateur astronomer Stuart Atkinson reveals 19 deep-sky highlights to track down with telescopes, including the wonderful Sombrero Galaxy featured on the cover this month.

We stay on those vast intergalactic scales thanks to science writer Govert Schilling, who looks at seven famous cosmologists who have pioneered the concept of dark matter – a term that was first used 100 years ago this month. Turn to **page 60** to discover what these seven scientists have added to our understanding of this mysterious form of matter, which best explains the view we see of the far-off Universe, but which has so far eluded all observation itself.

Yet, as well as concerning itself with the very largest scales, physics is also intent on investigating the very smallest. Philosopher Toby Friend investigates the reasons behind this seeming conundrum in our feature on **page 36**, and finds that advances in cosmology and particle physics have often been intertwined. Indeed, some of the biggest developments in our understanding of the Universe over the past century, from the make-up of stars to the observation of black holes, began with theories looking inside the atom.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 19 May.

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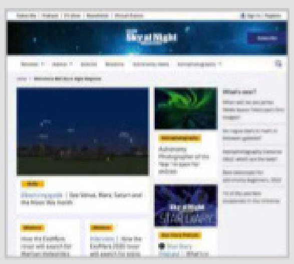
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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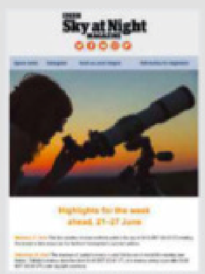

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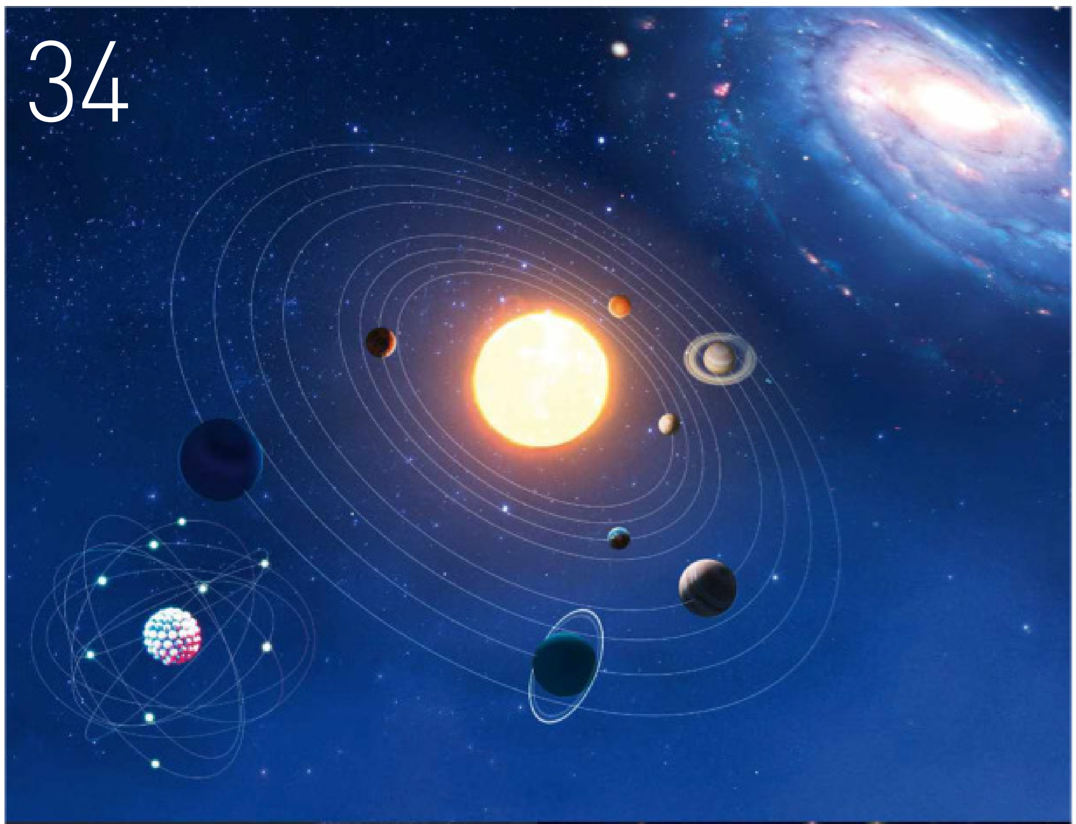
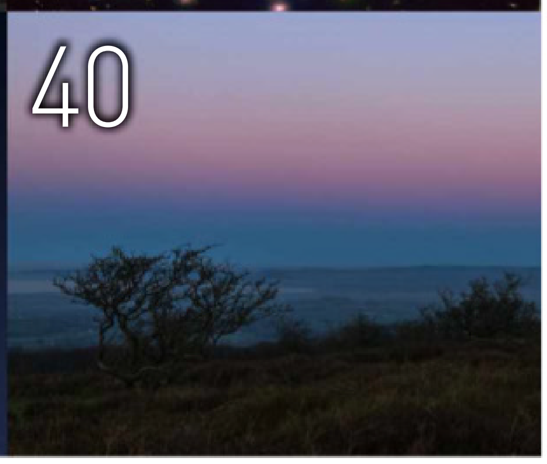
New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

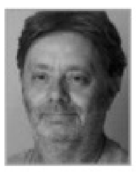




This month's contributors

Stuart Atkinson

Astronomer



"Just like Earth, the night sky has seasons too. Springtime is galaxy season, and there are plenty of beautiful deep-sky objects on show this month." **Take Stuart's spring galaxy tour, page 28**

Jane Green

Astronomy writer

"In our world of fully-automated Go-To scopes for viewing the night sky, I enjoyed being reacquainted with the nuts and bolts of celestial navigation." **Jane explains the way around the celestial sphere, page 72**

Katrin Raynor-Evans

Astronomy writer

"Having seen the Belt of Venus many times, it was great to delve deeper into the how and why of this beautiful twilight phenomenon." **Katrin looks at what causes the Belt of Venus and how to spot it, page 40**

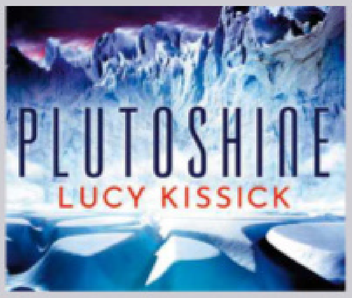
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/CVNU3XT/** to access this month's selection of exclusive Bonus Content

MAY HIGHLIGHTS

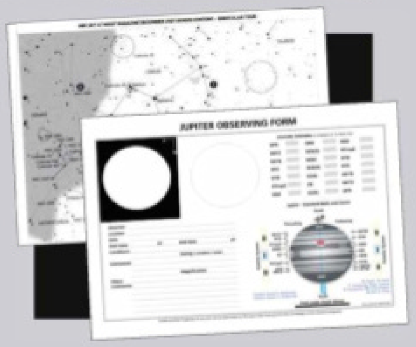
Interview: Hubble, Webb and exoplanets

NASA's Dr Richard Barry discusses the science of space telescopes and the hunt for distant worlds.



Book preview: *Plutoshine*

Download the first chapter of a new novel of sabotage and mystery set in a human settlement on icy dwarf planet Pluto.



Plan your observing for the month ahead

Access charts to record your observations of the planets and take this month's binocular and deep-sky tours.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

DAZZLING DESTRUCTION

An unusual triangular region of frenzied star formation blossoms following a head-on collision of two galaxies

HUBBLE SPACE TELESCOPE, 22 FEBRUARY 2022

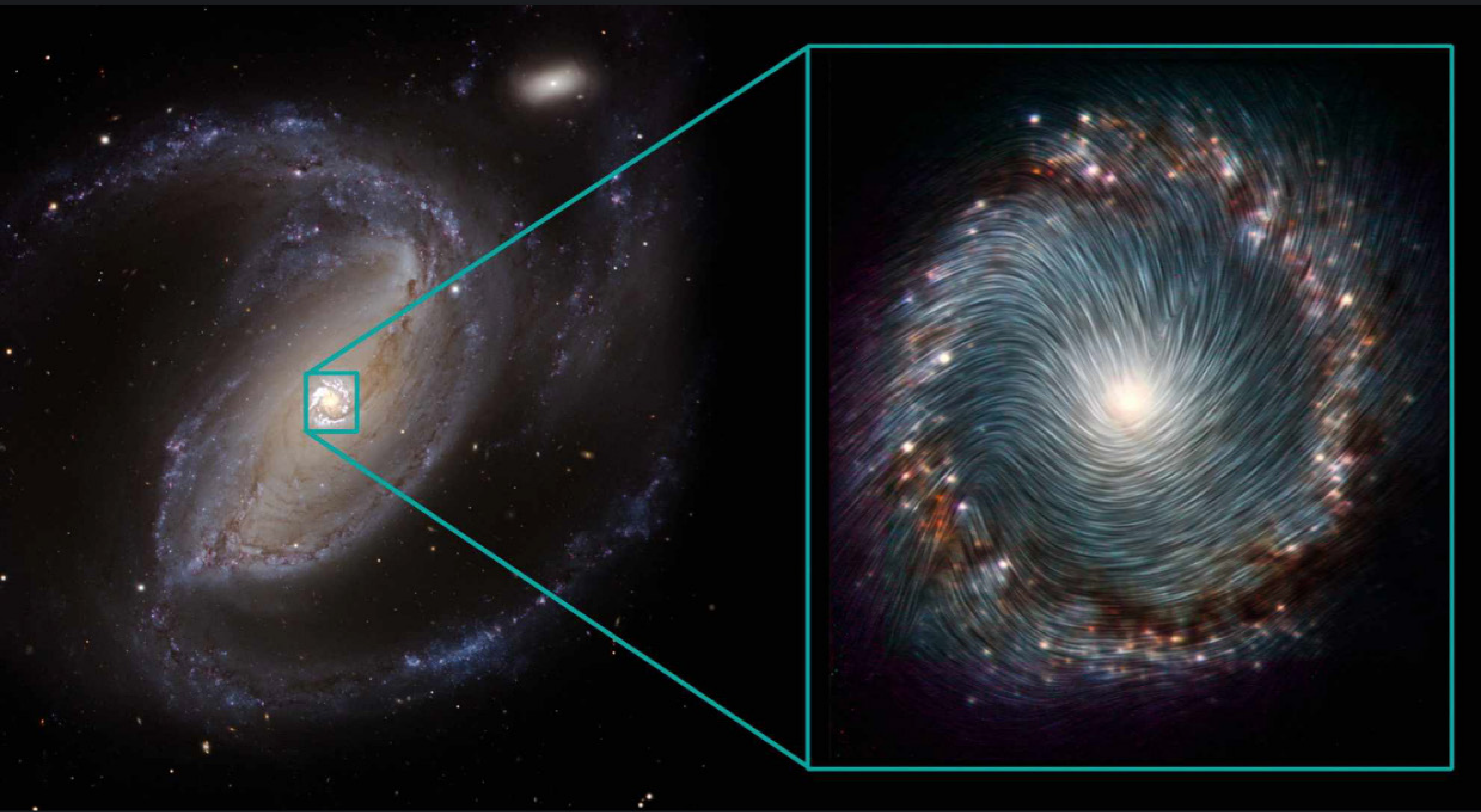
The two 'eyes' in this image are two galaxies left with dramatically different injuries after a direct collision millennia ago. On the left is elliptical NGC 2444, an indistinct haze of gas and dust and mostly elderly and dying stars. On the right is the vibrant NGC 2445, the apparent victor, that sports a beautiful 'black eye' from the skirmish: a glittering outer halo of bright, blue, newborn stars around the galaxy's core.

Collectively dubbed Arp 143 and found 181 million lightyears away in the constellation of Lynx, the duo highlight the intense star creation that can be triggered by some galactic collisions. But why the curious triangular shape? It seems that despite its worn-out appearance, the left galaxy is exerting control over its flashier sparring partner.

"Part of the reason is that these galaxies are still so close to each other and NGC 2444 is still holding on to the other galaxy gravitationally," says astronomer Julianne Dalcanton of the Flatiron Institute's Center for Computational Astrophysics. "NGC 2444 may also have an invisible hot halo of gas that could help to pull NGC 2445's gas away from its nucleus."

MORE **ONLINE**
A gallery of these and more stunning space images

NASA/ESA/STSCI, AND J. DALCANTON (CENTER FOR COMPUTATIONAL ASTROPHYSICS/FLATIRON INST./UWASHINGTON)



△ Feeding the beast

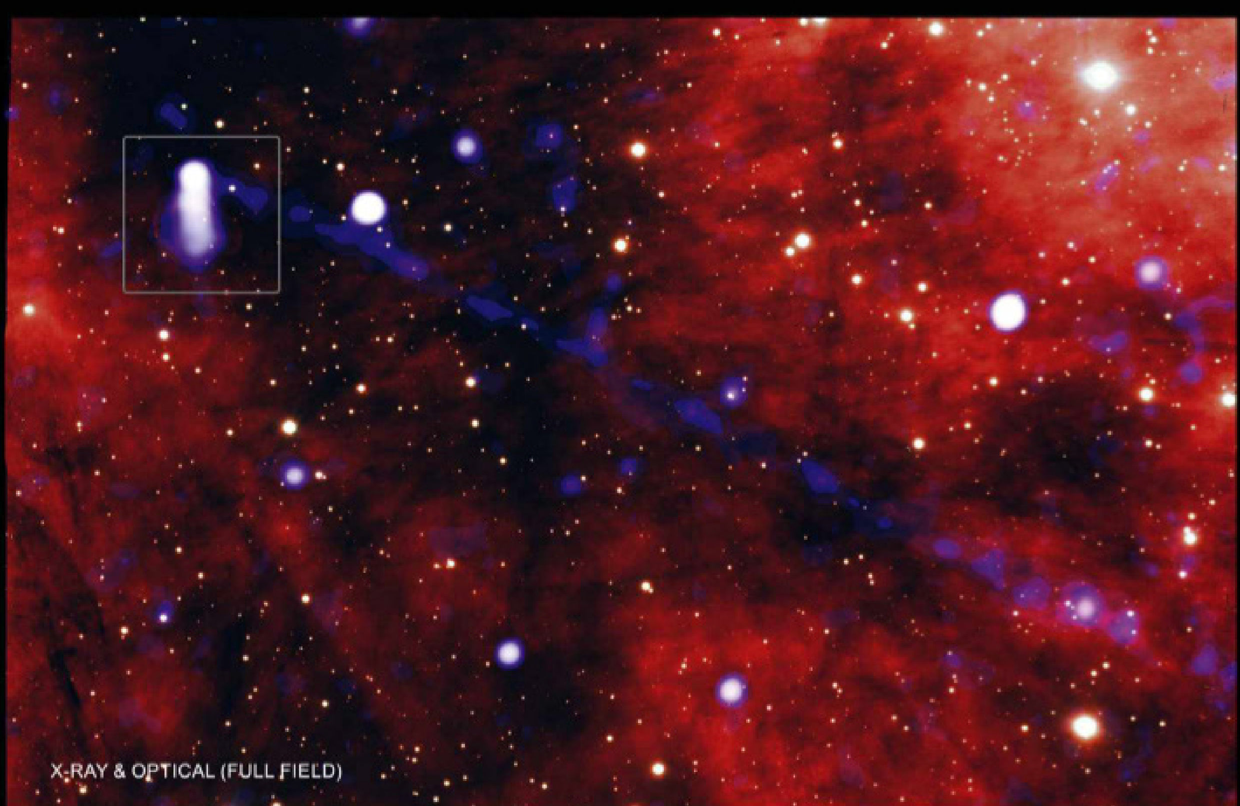
SOFIA, 22 FEBRUARY 2022

In the centre of NGC 1097, in the constellation of Fornax, the Furnace, a colossal black hole – 140 million times more massive than our Sun – drags in all the star-making gas and dust from its surroundings. But it's not just gravity that's funnelling the material inwards. Researchers using SOFIA, NASA's flying telescope inside a modified Boeing 747SP, have revealed that magnetic fields are at play (right), streaming matter from the arms of the host galaxy into the insatiable black hole.

▽ Pulsar-powered mega filament

CHANDRA X-RAY OBSERVATORY, GEMINI NORTH, 14 MARCH 2022

Newly detected filament PSR J2030+4415, 1,600 lightyears from Earth, is so large that only a third of its length could be captured in this image from the Chandra Observatory. The 64 trillion-kilometre-long beam of matter and antimatter is being emitted by a pulsar (close up, right) the size of a city. Spinning as it moves through space at 804,600km/h and leaking particles as it goes, the beam could explain the large amount of positrons detected in our Galaxy.



△ Alien bloom

CURIOSITY, 24 FEBRUARY 2022

It's good to stop and smell the flowers occasionally, and hardworking Curiosity – travelling around Mars for nearly 10 years now – recently took time out to photograph this 'bloom'. The floral-like rock formed from water-borne minerals in the Red Planet's wet, ancient past. Smaller than a penny, it was captured with the rover's Mars Hand Lens Imager (MAHLI). Curiosity is also capable of 'smelling' the 'flower': its onboard ChemCam fires lasers at rocks and soils to identify their chemical and mineral composition.

MORE ONLINE
A gallery of these and more stunning space images

◁ Spot the supernova

VERY LARGE TELESCOPE, NEW TECHNOLOGY TELESCOPE, 7 MARCH 2022

Can you spot the difference in the Cartwheel Galaxy between 2014 (left) and late 2021 (right)? The flash in the bottom left of the starry outer ring is a Type II supernova, the final act of a star collapsing after its fuel runs out. Dubbed SN2021afdx, it was first detected by the ATLAS asteroid early warning system in November and then captured here by the Faint Object Spectrograph on board ESO's New Technology Telescope.

SOFIA: ESO/PRIETO ET AL. (COLORSCALE), X-RAY: NASA/CXC/STANFORD UNIV./M. DE VRIES; OPTICAL: NSF/AURA/GEMINI CONSORTIUM, NASA/JPL-CALTECH/MSSS, ESO/INSERRA ET AL/AMRAM ET AL

JWST focused on the job ahead

The space telescope is nearly ready to begin scanning the infrared Universe

After weeks of alignment, NASA finished focusing the primary mirror of the James Webb Space Telescope (JWST) on 11 March, achieving a precision that exceeds the original goal.

The milestone marks the end of a procedure known as 'fine phasing'. JWST's main mirror is made up of 18 hexagonal segments; to focus these the team pointed the telescope at a lonely star chosen to be easily identified, with few nearby companions. They then adjusted each panel so that when combined, the 18 separate images were aligned into a single point of light, focused to within an accuracy of 50 nanometres – a fraction of the wavelengths of infrared light it will observe in.

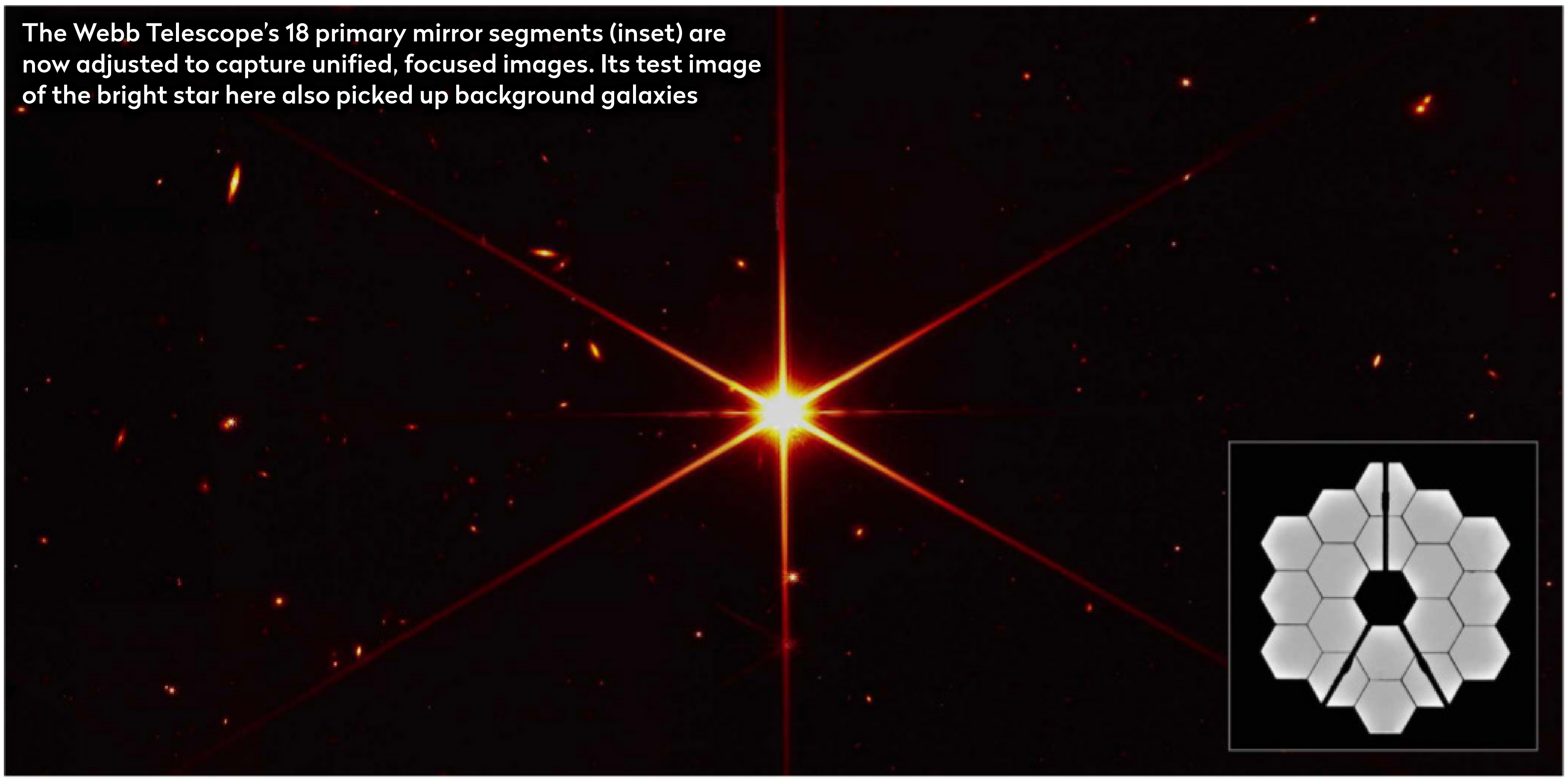
Next, the team imaged the star with the Near Infrared Camera. Even though this was only meant to pick up the focused star, the telescope captured a scattering of background galaxies as well.

"We have aligned and focused the telescope on a star, and the performance is beating specifications," says Ritva Keski-Kuha, Deputy Optical Telescope Element Manager for JWST.

The JWST team will now continue aligning the remaining optical elements of the telescope, aiming to conclude preparations in early May, before moving on to align the telescope's major science instruments.

"More than 20 years ago, the JWST team set out to build the most powerful telescope that anyone has ever put in space and they came up with an optical design to meet the science goals," says Thomas Zurbuchen, Associate Administrator for NASA's Science Mission Directorate. "Today we can say that design is going to deliver."

www.nasa.gov



The Webb Telescope's 18 primary mirror segments (inset) are now adjusted to capture unified, focused images. Its test image of the bright star here also picked up background galaxies

Comment

by Chris Lintott

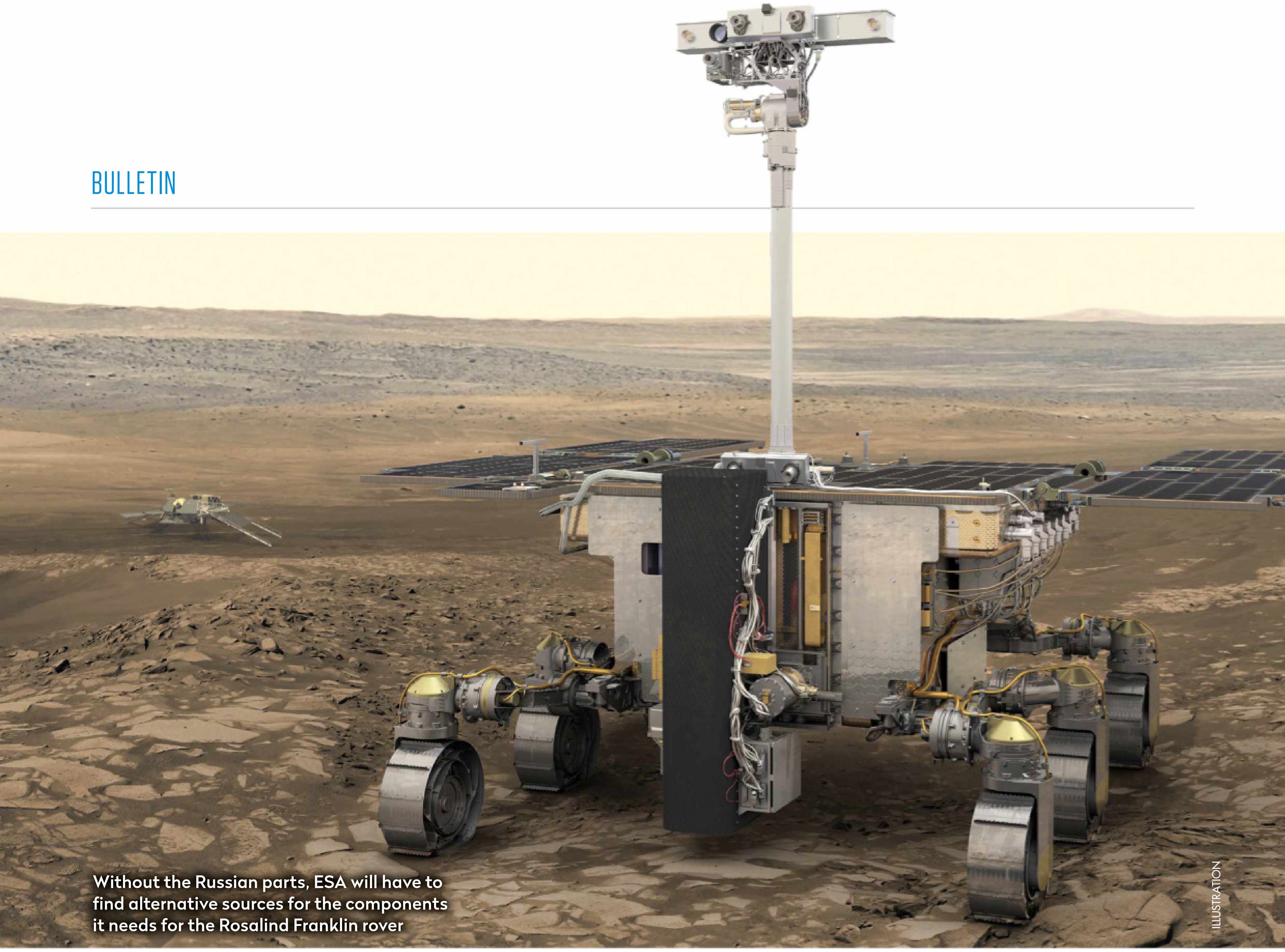
NASA/STSCI X 2

The first in-focus image from one of JWST's cameras (above) is tantalising, tempting astronomers with the promise of future riches. Compared to the previous infrared image of the region, from the Spitzer and WISE telescopes, which showed an array of blobs, Webb's image shows sharply focused galaxies that reveal structure in even these distant background sources. With the exceptional resolution of JWST, we can piece together the life stories of these obscure galaxies.

Although we only have access to this single image, we know the camera will have imaged the field through many filters. Looking at a galaxy's brightness in each of these would allow us to make a good guess at its distance, and hence how far back in the Universe's history we are seeing.

That's not the point of these images, as more will be coming soon, but it's a tempting idea!

Chris Lintott co-presents *The Sky at Night*



Without the Russian parts, ESA will have to find alternative sources for the components it needs for the Rosalind Franklin rover

Rosalind Franklin rover suspended

The consequences of big political shifts on Earth have reached as far as Mars

ESA/ATG MEDIALAB, NASA, NASA/CXC/M.WEISS, ESO/L. CALÇADA/ ALMA (ESO/NAOJ/NRAO)/A. POHL/VAN DER MAREL ET AL/BRUNKEN ET AL.

The Rosalind Franklin rover – the latest ESA (European Space Agency) Mars mission that was scheduled for launch this September – has been suspended as part of ESA's move to cut ties with Roscosmos, the Russian space agency. The move comes in response to the war in Ukraine.

The rover was meant to use its 2m drill to probe deeper beneath the Red Planet's surface than any previous mission, hoping to find signs of past life. Roscosmos is supplying several key components of the mission, most notably both the launch rocket and the Kazachok landing platform that would carry the rover to the Martian surface. But in a meeting on 28 February, the 22 member states of ESA asked the agency to enforce sanctions against Russia. Then, on 17 March, ESA announced it would be suspending Rosalind Franklin's launch and seeking to replace all Roscosmos components required for the mission.

"The decision was made that this launch cannot happen, given the current circumstances and especially the sanctions that are imposed by our member states," said ESA Director General Josef Aschbacher. "This makes it practically impossible, but also politically impossible to have a launch of [the rover] in September."

ESA is looking into ways it can continue without Roscosmos, such as working with NASA. But the mission would need to be extensively reworked and wouldn't be ready until 2026 at the earliest.

The mission is just one of many that have been affected. ESA has ceased all Soyuz launches from its facility in French Guiana, while Russia has broken several contracts to supply parts in response.

One place that both ESA and NASA continue to cooperate with Roscosmos, for the time being, is aboard the International Space Station. The station is specifically designed to require the involvement of all parties to function, and Roscosmos is responsible for maintaining its orbit. Roscosmos is only contracted to support the station until 2024, however. The agency was in talks to renew its commitment until 2031, when the station was due to be decommissioned, but the head of Roscosmos Dmitry Rogozin has made comments about withdrawing support, should the sanctions continue.

"We'll closely monitor the actions of our American partners and if they continue to be hostile, we'll return to the question of the existence of the International Space Station," said Rogozin.

www.esa.int

Artemis I rocket reaches launch pad

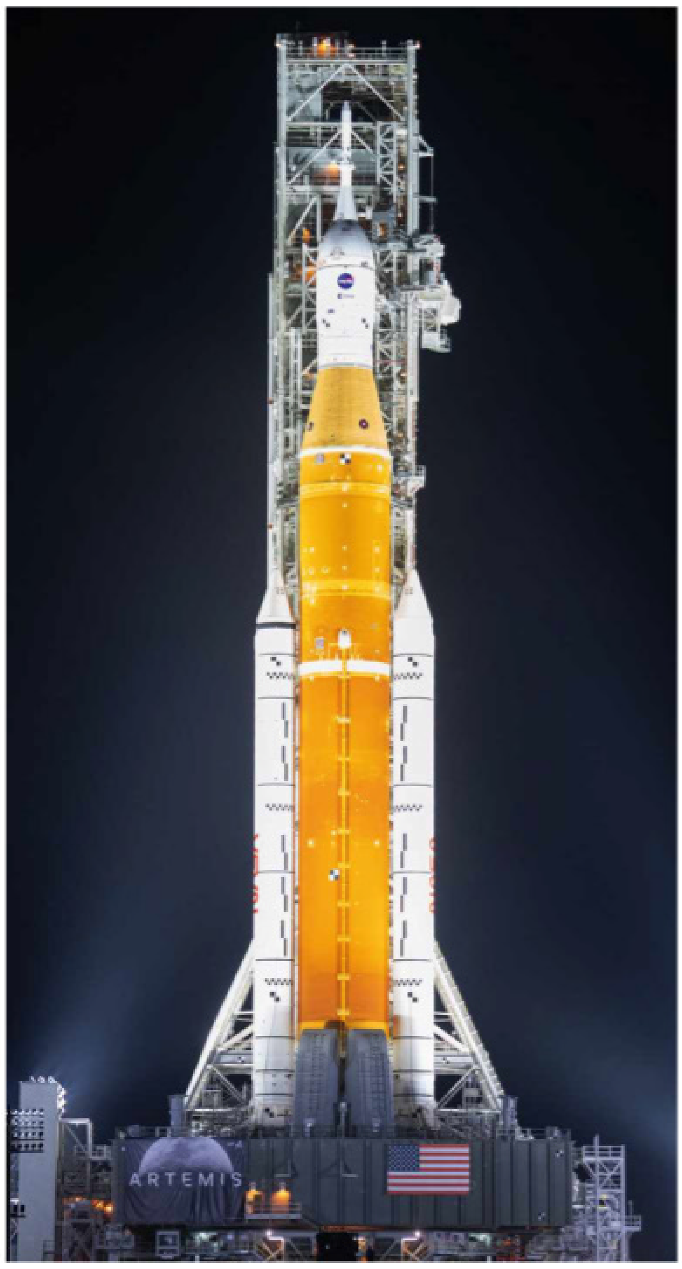
Rocket bound for the Moon set for launch rehearsal

NASA's Space Launch System (SLS) rocket, topped with the Orion spacecraft, which together form the Artemis I mission, finally made it to the launch pad on 18 March. The 6.4km journey from the building where it was assembled to launch pad 39B took the 98m-high rocket 10 hours and 28 minutes.

"Rolling out of the Vehicle Assembly Building is an iconic moment for this rocket and spacecraft, and a key milestone for NASA," said Tom Whitmeyer, Deputy Associate Administrator for Common Exploration Systems Development. "Now, we'll use the integrated systems to practise the launch countdown and load the rocket with the propellants it needs to send Orion on a lunar journey."

This so-called 'wet dress rehearsal' will be the last test before launch, which is currently expected to occur no earlier than late May or June. This uncrewed mission serves as a test of NASA's Artemis programme, which aims to return humans, including the first woman, to the surface of the Moon.

www.nasa.gov



▲ NASA's SLS rocket and Orion spacecraft have been rolled out to the launch pad to rehearse fuelling and launching procedures

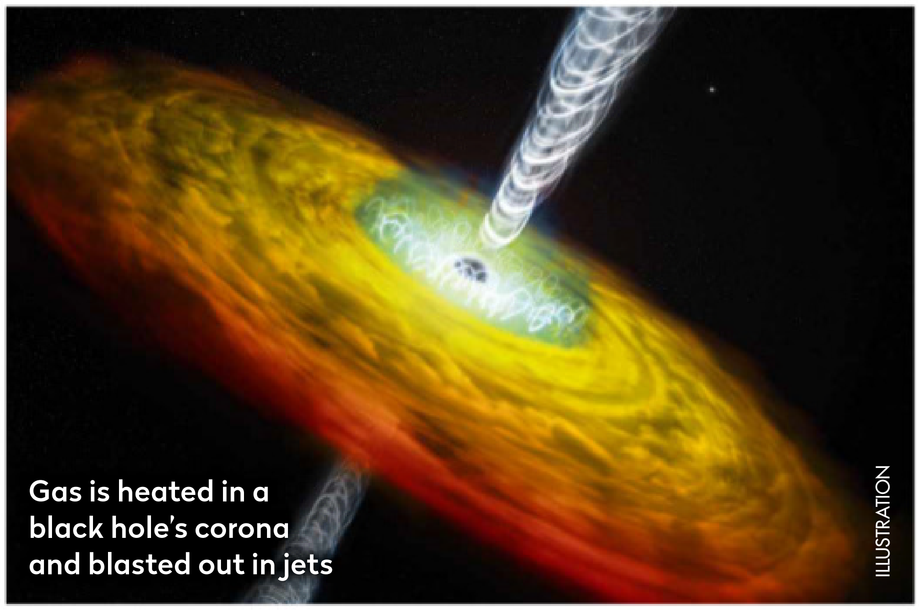
The beating heart of a black hole

For the last 15 years astronomers have been taking the pulse of a distant black hole, watching how its energy output rises and falls. Finally, they have now confirmed a long-held suspicion that black holes collect and heat gas in a surrounding corona before spitting it out in colossal jets.

"It sounds logical, but there has been a debate for 20 years about whether the corona and the jet were simply the same thing. Now we see that they arise one after the other and that the jet follows from the corona," says principal investigator Mariano Méndez from the Kapteyn Institute. "It was quite a challenge to demonstrate this sequential nature. We had to compare data of years with that of seconds, and of very high energies with very low ones."

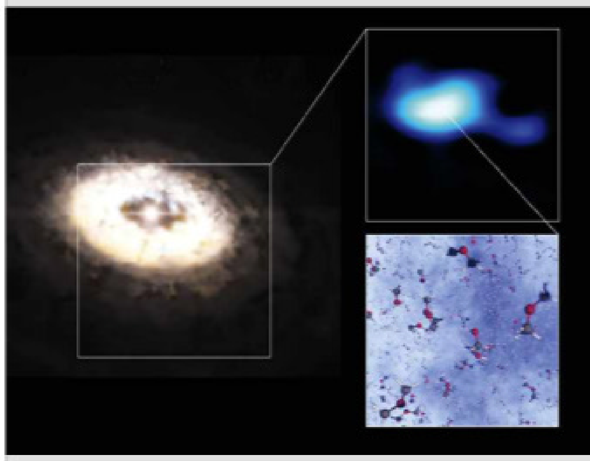
Observations of high-energy X-rays coming from the corona showed more energy than could be explained by normal heating. A possible explanation is that the black hole's magnetic field occasionally becomes chaotic, adding energy to the corona, before becoming ordered again and ejecting the jets along its field lines.

www.rug.nl



Gas is heated in a black hole's corona and blasted out in jets

NEWS IN BRIEF



Large molecule found in planet growing disc

Dimethyl ether (inset, above), a complex organic molecule made up of nine atoms, has been detected in the planet-forming disc around a star (IRS 48, above, left) for the first time. Not only is this the largest molecule ever discovered in such a disc, but such chemicals play a key part in starting life.

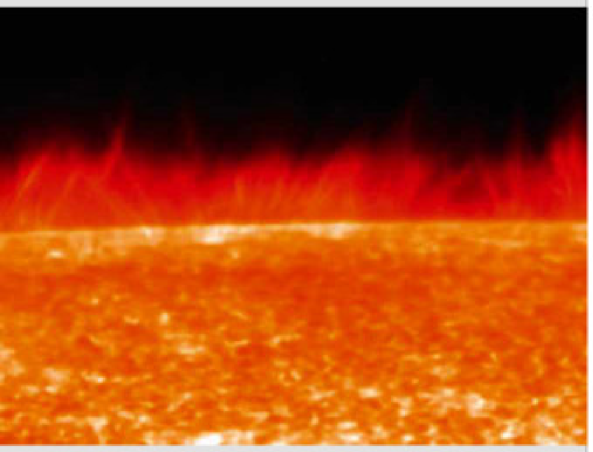
No black hole 'nearby'

The 'closest' black hole system to Earth, located just 1,000 lightyears away, may not contain a black hole after all. The system was first reported in 2020, but now two independent teams have determined it could instead be a double star system, where one member has had its outer layers stripped by its companion.

5,000 exoplanets confirmed

NASA's list of confirmed exoplanets passed the 5,000 mark on 21 March, 30 years after the discovery of the first. Doubling that number could happen much quicker, as there are already 5,000 candidate exoplanets found by the TESS exoplanet telescope awaiting confirmation.

NEWS IN BRIEF



Alligator song helps heliophysicists

The answer to the mystery of how the Sun forms jets of plasma 10,000km-high could lie in an unexpected place – alligator mating calls. The reptile's bass bellows make the water around them jump and dance in much the same way as seen on the surface of the Sun.

Lunar oxygen extraction

UK company Thales Alenia Space has won an ESA contract to build an experiment to extract oxygen from the lunar surface. Although this experiment would only extract 50–100g of oxygen, the technology could one day be used to help support astronauts living and working on the Moon.

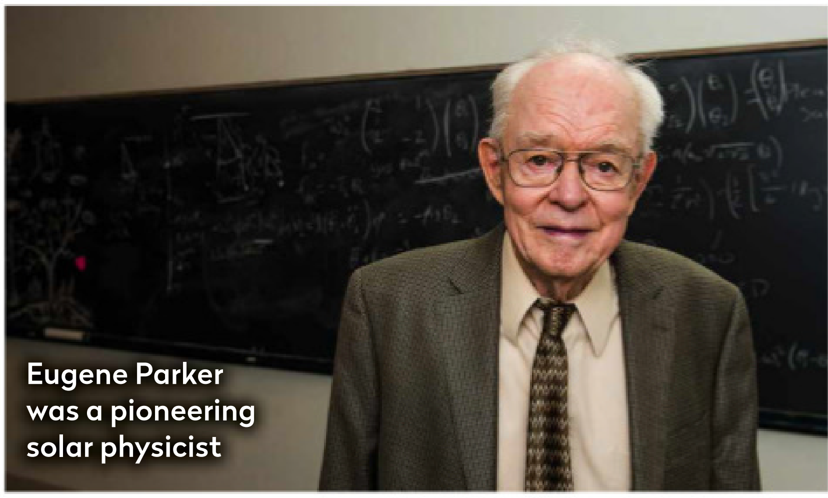
Pluto's recent eruptions

Pluto's surface may have been shaped by cyrovolcanism – where water acts like rock and lava – much more recently than previously thought. New analysis of images from NASA's New Horizons probe show that the ice volcanoes Wright Mons and Piccard Mons have a distinct lack of impact craters.

NASA'S GODDARD SPACE FLIGHT CENTER/JAXA/NAOJ/NASA/JAXA/HINODE, NASA/GLENN BENSON, NASA/LRO

Eugene Parker dies, aged 94

He predicted the solar wind and shape of the Sun's magnetic field



Eugene Parker was a pioneering solar physicist

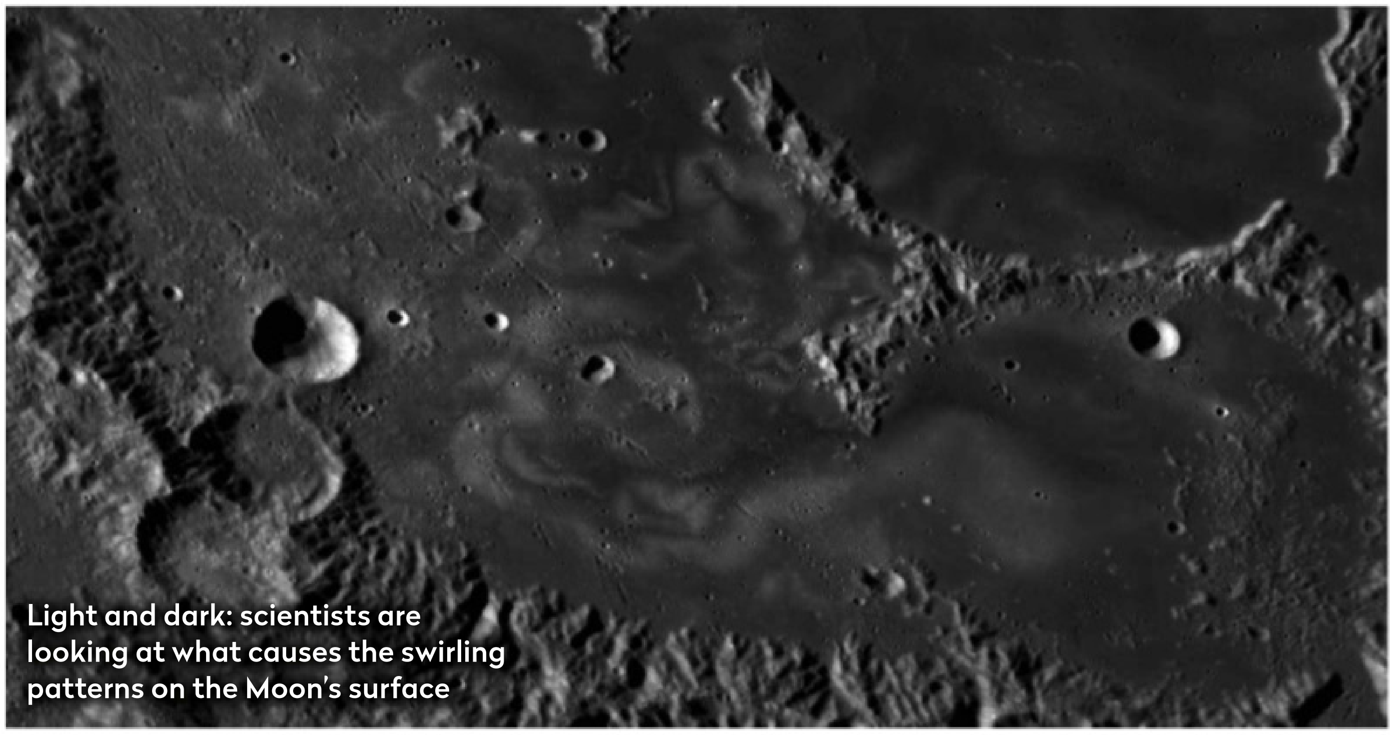
The visionary solar scientist Eugene Parker, whose name graces NASA's Parker Solar Probe, passed away on 15 March at the age of 94.

In the mid-1950s, Parker developed the theory that predicted particles would flow out of the Sun, a theory that was proved correct in 1962 when Mariner 2 measured the solar wind. He also correctly hypothesised that the solar magnetic field would take on a spiral shape in the outer regions of the Solar System, due to rotation of the Sun's magnetic field.

"The field of heliophysics exists in large part because of Dr Eugene Parker," says Thomas Zurbuchen, NASA's associate administrator for science. "Honouring his work by giving Parker Solar Probe his name is one of the proudest accomplishments of my career. Parker Solar Probe 'touching the Sun,' is a fitting accomplishment for his namesake mission."

http://parkersolarprobe.jhuapl.edu/

Lunar swirls highlight the landscape



Light and dark: scientists are looking at what causes the swirling patterns on the Moon's surface

The Moon's plains have swirling patterns of light and dark, but it's been unclear until now whether these are patterns in the dust or if they reflect the topography of the landscape.

Previously it was thought the colour changes were created by the solar wind reacting to magnetic fields within the rock. However, a new study has shown that in two swirl regions of Mare Ingenii the dark areas are higher in elevation, while the lighter streaks are lower.

"This correlation argues that there is more than just shielding from space weathering that goes into their creation," says Deborah Domingue Lorin from the Planetary Science Institute. "The question becomes about how much we understand the processing of the lunar surface and the migration of fine-grained materials. If we are going to have long-term installations on the Moon's surface, how do we protect against issues that fine-grained dust present to robots, habitats, space suits and machinery... and the health and safety of humans on the surface for long durations?"

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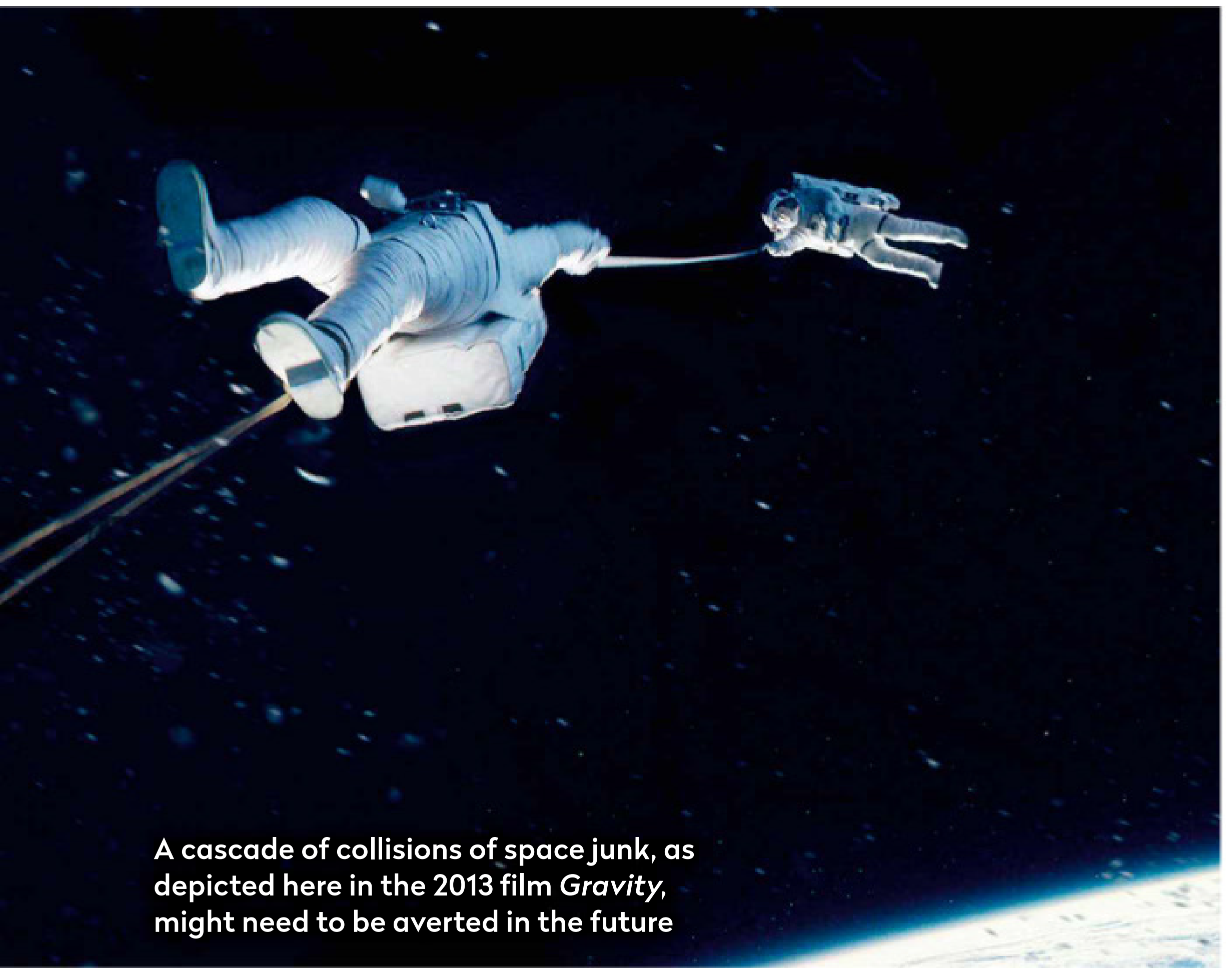
Our experts examine the hottest new research

CUTTING EDGE



A cascade of collisions of space junk, as depicted here in the 2013 film *Gravity*, might need to be averted in the future

A space junk timeline

Free-for-all access to low-Earth orbit is increasing the risk of collisions

Space is getting increasingly crowded. At least, it is in the region of low-Earth orbit, where many satellites operate. Spanning altitudes between about 160km and 2,000km above Earth's surface, low-Earth orbit requires less fuel to reach than higher orbits. Its relative proximity to the ground also provides advantages for low-powered communication devices, such as Iridium satellite phones, as well as for Earth observation – think weather-forecasting, monitoring the environment and spying. The International Space Station (ISS) and China's Tiangong space station also occupy low-Earth orbit, both at an altitude around 400km.

There are plenty of objects, however, that have fallen out of use and remain in orbit. Satellites can remain in position long after they have stopped functioning and the process of launching them is also a decidedly messy affair: spent rocket stages and separation bolts also contribute to the debris circling around Earth. All of this space junk is moving at speeds of up to 28,000km/h and as it continues to accumulate it poses an increasing risk of collision. For example, in the 20 years of its operation, the ISS has had to shift around 30 times to avoid being hit by orbital debris. But the problem isn't just the risk of a collision, because a satellite hit by debris can shatter into thousands of fragments, any of which can go on to collide with other satellites and so on. This could potentially trigger a runaway cascade of satellite destruction – a chain reaction of collisions – until a whole region of orbital space is so full of hazardous debris that it's rendered unusable or impassable for decades. This possibility is known as the Kessler Syndrome, and will be familiar to anyone who's watched the film *Gravity*. In the worst case scenario, it could block human access to space and end services such as GPS and satellite imaging for a long time.

What are the odds?

As more and more satellites are launched into low-Earth orbit, the risk of a catastrophic Kessler Syndrome, and the huge economic impact it would have, only increases. But how likely is it to occur?

Two economists, Akhil Rao, at Middlebury College, Vermont, and Giacomo Rondina at the University of California, San Diego, have been studying the problem. They've built a model that not only considers the orbital dynamics involved in a Kessler Syndrome occurring, but also the changing economics of satellite launches. They note that, currently, orbital space is effectively open access – anyone who can build a rocket is able to place as many satellites as they like in any orbit they choose.

"A satellite hit by debris could shatter into thousands of fragments, any of which could go on to collide with other satellites"

Rao and Rondina focused on the orbital shell, between the altitudes of 600km and 650km, which lies at the edge of the region where Earth's thin, upper atmosphere will naturally de-orbit debris within 25 years. Based on the recent growth of the space sector, they calculate a Kessler Syndrome would occur around 2048. But if launches increase more quickly, it could even happen as early as 2035. Possible solutions to avert the problem include technology to actively remove debris from low-Earth orbit, or new international laws to limit and control the number of launches.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading… *Open access to orbit and runaway space debris growth* by Akhil Rao and Giacomo Rondina.
Read it online at: arxiv.org/abs/2202.07442

Big stars come with an entourage

A closer look at seemingly lonely massive stellar objects reveals they're rarely without companions

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Among the glories of Sagittarius, the king of the southern summer sky, M17 deserves to be better known. Just about visible to a keenly sighted naked-eye observer, the Omega (also called the Swan or Lobster) Nebula may lack a distinct form, but it is substantial. Lying between 5,000 and 6,000 lightyears away, it contains more gas – fuel for star formation – than the Orion Nebula, making it one of the best laboratories we have for understanding how stars form.

We look to M17 to help us understand the formation of the most massive stars, those with more than eight times the mass of the Sun. A cluster of these, formed within the last few million years, sits at the heart of the nebula and this month's paper takes a closer look at them than ever before. The team behind the paper used the marvellous GRAVITY instrument attached to the Very Large Telescope (VLT) to get extremely high-resolution images of the nebula's core, with the aim of identifying any companions to the massive stars that live there.

The question of whether the largest stars have companions, and what they're like if they do exist, is thought to be important in trying to understand the process by which such massive stars form. All star formation is a race, between the processes by which material is accreted onto the forming protostar and those that will power the nuclear fusion at the star's core. Once the latter get going, powerful stellar winds will prevent further accretion and growth, cutting off star formation, so any massive star needs to form quickly.

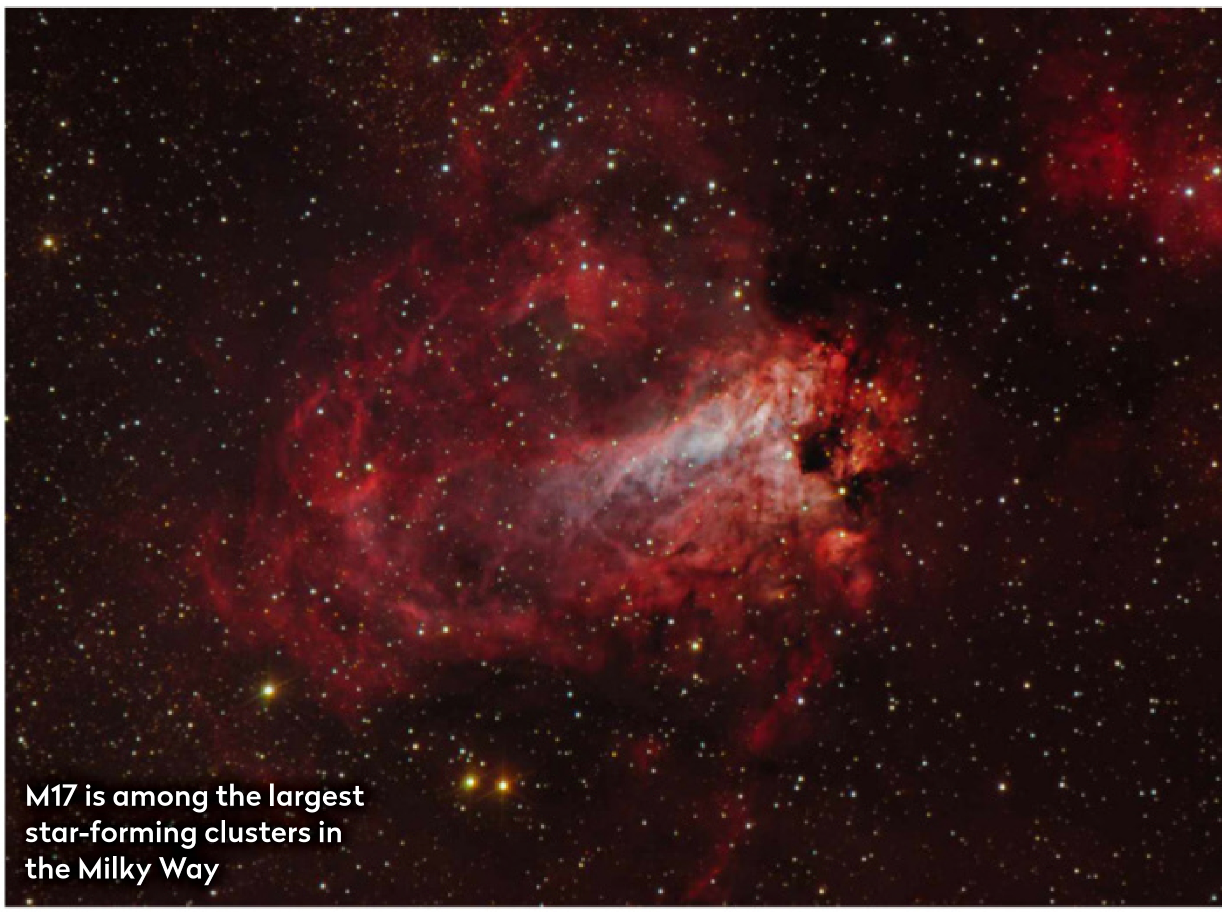
Missing companions

Theories of massive star formation range from the merging of smaller protostars, to interactions in dense clusters of new stars, to extreme examples of the processes that drive the formation of normal stars. Each of these possibilities will have left its mark on the population of binary stars in M17. Previous studies used spectroscopic techniques to try and pin down the fraction of massive stars in this young cluster that have companions, and seemed to show that the cluster was unusually devoid of such systems. This made it an intriguing target for GRAVITY, which is capable of finding more distant and less-massive companions.

"Massive companions are common in M17, meaning massive binaries must form early in the evolution of such a system"

Sure enough, all six of the stars targeted in the cluster turn out to have at least one companion, sharing 14 between them, with masses ranging from three to 50 times that of the Sun. That's enough to conclude that, as in other clusters that have been studied, massive companions are common in M17, meaning massive binaries must form early in the evolution of such a system.

We can also say more about the binaries: there is a wide variety of separations, from stars not much further apart than Earth and the Sun, to those that are 120 times that distance apart, and a distinct lack of systems in which the two stars are of equal mass. Unfortunately, no one theory of massive star formation explains all of these features, so all we can really say is that more observations are needed. Luckily, with GRAVITY and the Very Large Telescope, astronomers have the tools to do the job.

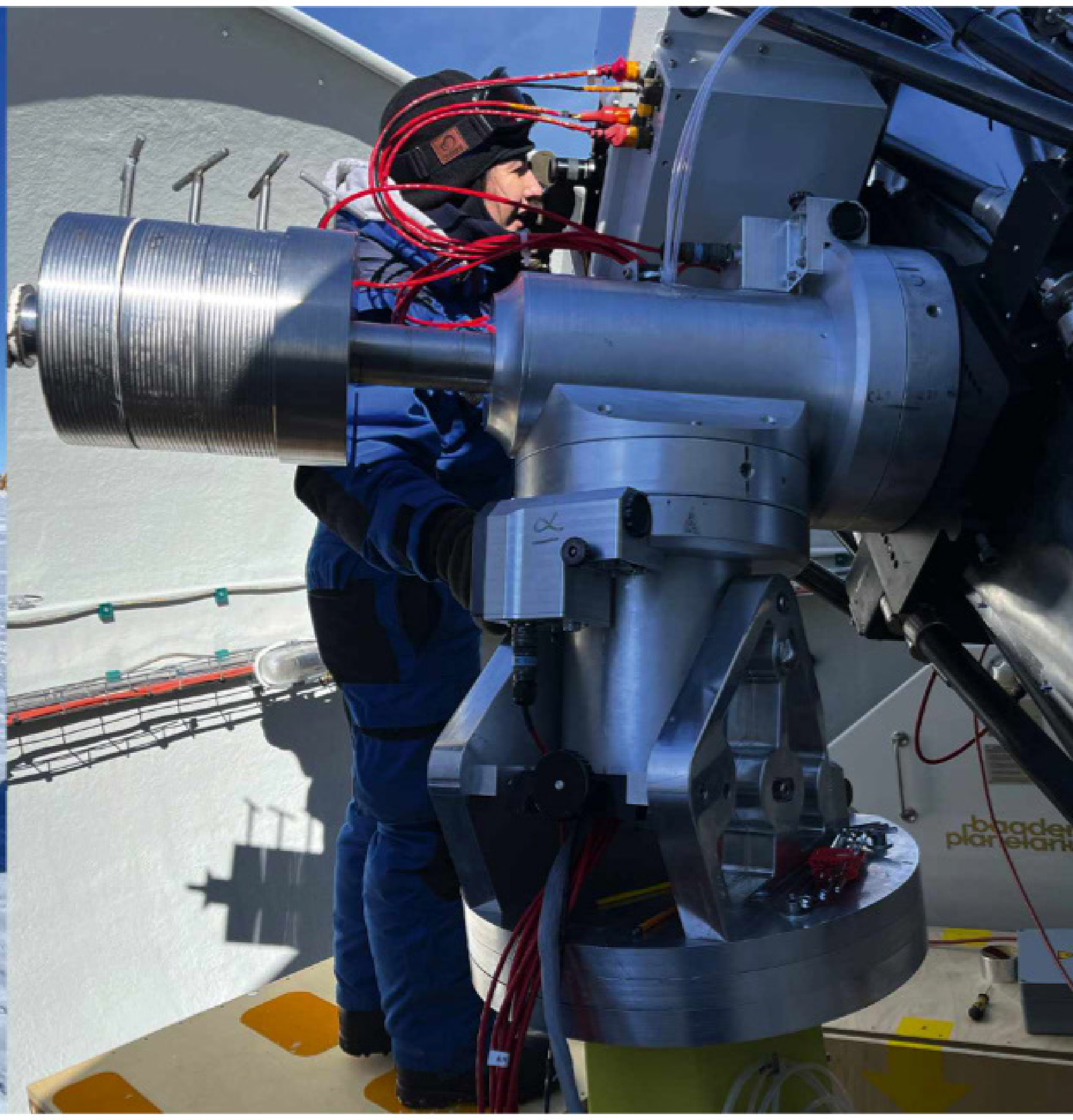


M17 is among the largest star-forming clusters in the Milky Way

Chris Lintott was reading... *On the origin of close massive binaries in the M17 star-forming region* by E Bordier et al.
Read it online at: arxiv.org/abs/2203.05036

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



ILLUSTRATION

Georgina Dransfield visited Antarctica to search for exoplanets and filmed her time there for the April episode of *The Sky at Night*

▲ **Left: Georgina Dransfield (second from left) braved the elements with her colleagues at the Antarctic Search for Transiting ExoPlanets (ASTEP)...**

Right: ...where she used the project's 40cm telescope

Although it might seem unlikely, jealousy can be a healthy motivator. In my previous life as a secondary school physics teacher, I was often jealous of my students. They'd attend my lunchtime Exoplanets Club, or come to my Astronomy Olympiad prep sessions, or even spend weekends with me at the UK Space Design Competition. Watching them get so excited about space science, and seeing how it was shaping their ambitions and future plans, was really what led me to say, "I want to do that too".

So that is what I did and four years later, I was celebrating the arrival of 2022 at one of the world's most inhospitable places: Antarctica's Dome C. Why was I there? My task was to install some software on a telescope's computer at a remote research station.

When you stop and think about it, there's something lovely about the juxtaposition of ASTEP and its surroundings. ASTEP is the Antarctic Search for Transiting ExoPlanets, a 40cm telescope at the Concordia Research Station, located at Dome C. The project's goal is to find distant worlds orbiting faraway stars, in the hope of one day stumbling across a planet capable of hosting life. The reason I find this poetic is because Dome C is absolutely not capable of hosting life. For starters, the cold conditions are barbaric (between –30˚C and –50˚C in summer and as low as –85˚C in winter); then there is the impossibly dry air, the Sun's refusal to behave normally (day and night cycles are daft this close to the poles), and the pathetically low atmospheric pressure. All these factors make it an exhausting and expensive endeavour to exist in Antarctica, but they also make it the best place on Earth to hunt for exoplanets using the transit method.

GEORGINA DRANSFIELD X 3

Signals of life

In our quest to find planets that aren't too up close and personal with their parent stars, we must inevitably search for signals that are both long in duration and infrequent in occurrence. Our own

Georgina Dransfield is an Anglo-Uruguayan teacher-turned-Astro-PhD student at the University of Birmingham

Earth as viewed in transit by (probably) clever alien astronomers would cast a roughly eight hour-long shadow on the Sun, only once every 365 days. Signals like these need long, uninterrupted and clear nights, with very stable conditions. ASTEP enjoys all of these, simply by virtue of its location.

Throughout my PhD I have been working with the ASTEP team, most of whom are based at the Côte d'Azur Observatory in Nice. My jobs are the fun bits: I choose which planet candidates we will be observing; I juggle the schedule to ensure we make the most of our available observing time; and I get to analyse the data for planets we think we've validated. Recently, I also took on the development of new automatic data analysis software for the telescope, which meant I got to go along on a summer service mission to Antarctica to install and test the package.

During my stay at Concordia Research Station, I reflected on all the twists and turns in my life that led me to Antarctica on the hunt for extra-solar planets. I'm sure thousands of immeasurably small moments led me there, but by far the biggest contributors were my wonderful students: their excitement about astronomy inspired me to go back and learn more cool facts about space. I hope one day I'll be back in a classroom to share everything I've learned.

Looking back: The Sky at Night

26 May 1970

In the 26 May 1970 episode of *The Sky at Night*, Patrick Moore visited the home observatory of Frank Acfield – an amateur astronomer and vice-president of the Newcastle upon Tyne Astronomical Society.

▲ **Patrick Moore (right) visits the Forest Hall home observatory of Frank Acfield**

Before 1949, Acfield had his 10-inch Newtonian telescope set up in his back garden, and fellow society member John Croften offered to build him a custom observatory dome. It took 12 months to build the dome, mainly out of wood which was then painted with white aluminium paint to reflect the Sun's radiation and keep it cool.

Patrick was keen on the on-site dark room and projector. As this was long before the days of digital cameras, the scope's camera had to use photographic plates to capture the stars. A facility to develop plates as they were taken meant that Acfield could be sure he was getting the best images and that the tracking of his mount – powered by the electric motor from a gramophone – was working well.

Acfield sent his observations to the British Astronomical Association (BAA), to be used by scientific institutions. Both he and Patrick were keen to point out that astronomy is a science where amateurs can contribute to actual scientific discovery.

If you're interested in setting up a home observatory, sign up for our Telescope Masterclass series at **bit.ly/3Li3xEU**

Destination Moon

Fifty years since humans last stood on the Moon, the team look back at the Apollo programme and anticipate NASA's upcoming Artemis project, which promises to return crew to the lunar surface in 2025. Plus, they'll reveal how to observe the total lunar eclipse on 16 May, and why the Moon is a great target for astronomy newcomers.

BBC Four, **9 May**, 10pm (first repeat
BBC Four, **12 May**, 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **NASA's Artemis programme aims to put humans back on the Moon in 2025**

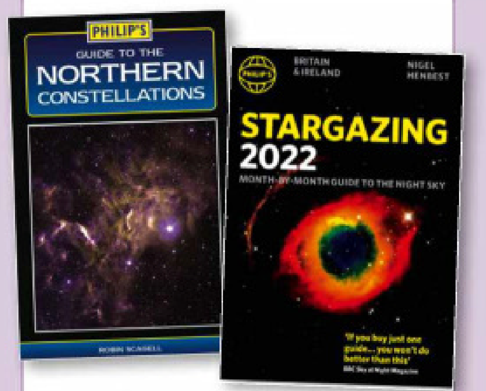
Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles



The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2022* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Ted in space!

My name is Freya. I am nine years old and a Brownie Guide. For my Brownie space badge I had to learn some constellations, make a sunspot viewer from a cardboard box and design a spacesuit. I chose to do a spacesuit for my teddy bear, Padstow. I made it out of recycled cardboard, foil and pie dishes. To look like Space Ted was floating in space, we showed a picture on the TV that my grandpa took, hung Padstow in front of the TV and took a photo. I hope you like it.

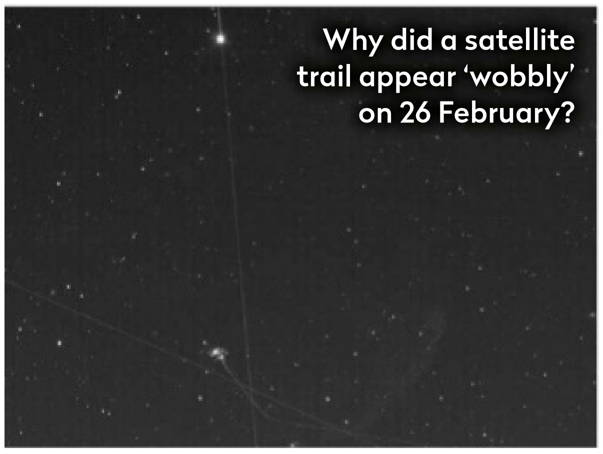
Freya Hunt, Cheshire

That's a fantastic spacesuit Padstow is wearing, Freya, and a very imaginative way to present him against your grandpa's picture. Your space badge has been well-earned! ***– Ed.***

Freya's Space Ted takes a giant leap

Tweet

Gill Prince
@GillPrincePhoto • Mar 18
Such a fab moonrise this evening over #MiltonKeynes – and yes, it really was that colour! @SES_Satellites @scenesfromMK @BBCStargazing @skyatnightmag



Why did a satellite trail appear 'wobbly' on 26 February?

Trail finder

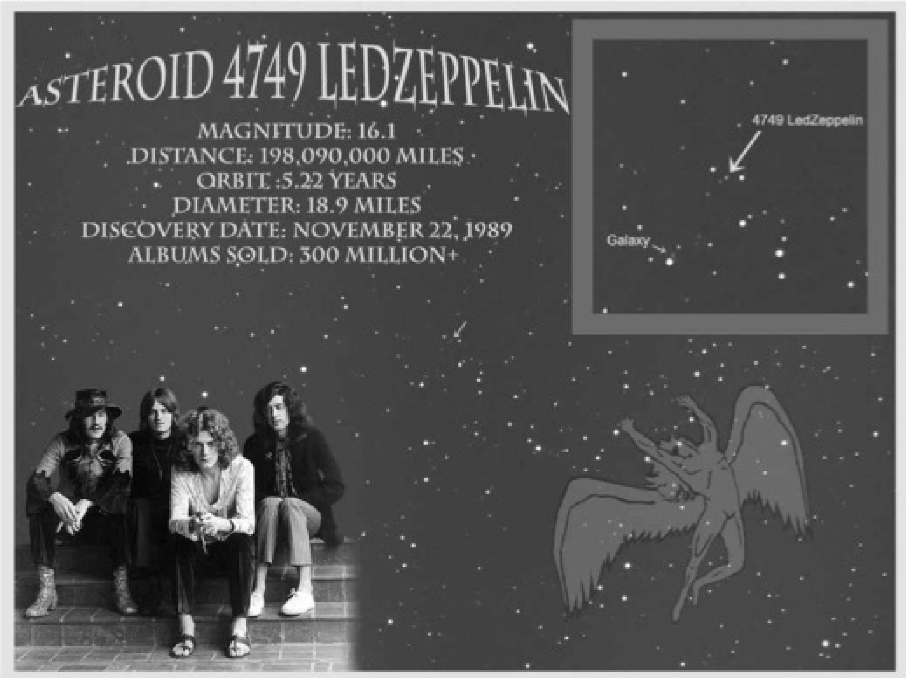
I wonder if anyone can help me with a picture I captured during an imaging session on 26 February 2022 at around 22:08, with a 120-second exposure. My imaging target at the time was the Jellyfish Nebula, IC443, but I noticed one of the satellite trails veers sharply upwards in the image before going wobbly and ending in what also looks like a nebula. I wonder if inadvertently I have captured a dying satellite falling towards Earth? I would appreciate any help with this as my curiosity is intense.

Robert Bowers, via email

On the right track

After reading the article about how the Milky Way got its name on your website (**bit.ly/37ODFSz**) I wanted to offer the following thoughts. The two composite words of 'galaxy' are Greek, unlike Latin: ΓΑΛΑ (gala) = milk and ΑΞΩΝ (axion) = axis. 'Planet' comes from the Greek ΠΛΑΝΗΤΗΣ (planetes), which is the adjective of the Greek ΠΛΑΝΗ (plane) = fallacy, delusion, errancy; which I imagine is down to a planet's track in the sky not being constant, unlike the Sun or Moon's. It is the same root as 'aeroplane', another object whose track is also not constant.

George Vakos, via email



▲ Stephen pays tribute to asteroid 4749 LedZeppelin

Space rock!

Recently, I set an interesting project for myself. Early on, newly discovered asteroids were named after Roman gods or Greek mythological creatures, but as the numbers grew into the thousands, naming asteroids required a wider range of sources. That's why there's a list of asteroids named after celebrities, sports figures and musicians.

I chose to find and image 4749 LedZeppelin, which is nearly 26,000 times fainter than the dimmest star you can see with the naked eye. Here's what I came up with (above).
Stephen LaFlamme, Bridgewater, Massachusetts, USA

A bright star

Do you know the meaning of Sirius? I would like to tell my grandson the meaning of his name. His birthday is coming up and I thought it would be special if I could let him know where his name comes from. He is a very bright star in my life.
Yvonne Sawyer-Bailey, via email

What a wonderful birthday gift, Yvonne! If he's a bright star in your life you'll be happy to know that the word Sirius means 'glowing' in ancient Greek. As it is the brightest star in the sky, the ancients probably thought it was a good title. It's also known as 'the 'Dog ▸

ON FACEBOOK

WE ASKED: Would you like to visit a settlement on the Moon? How would you spend your time?

Stephen Dink Williams Obviously I would tell Elvis to go home because everyone is missing him.

Martin Bailey Not particularly. I love a party with a heavy atmosphere.

Kevin Nolan I'd take a few 'choice' world leaders who seem to be lacking some badly needed global perspective.

Emma Hugo Yes I would love to go with my fellow star lady Carol Miller. I have a keen eye for all things geology so I would probably be looking at the ground and I'm sure Carol would be taking pictures of Earth. I would love to jump into a crater.

Carol Miller I would like to go before it becomes too much of a junkyard and too busy. Being on the Moon and being able to see Earth would be out of this world. Sorry for the pun.

Bob Kelly My wife and I love to travel together. We'd go out on excursions – perhaps to Hadley Rille for the towering, scenic mountains and to see (from a distance) the Lunar Rover and Lunar Module decent stage left behind.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Celestron NexStar Evolution Schmidt-Cassegrain Telescope, which I use with Baader Hyperion and Morpheus eyepieces. Can I use these with my Canon Ti5 Rebel DSLR camera?

YVONNE BENNETT

These eyepieces can be used with a DSLR camera as you suggest, but they cannot be used with a DSLR on its own as the eyepieces still need to be inserted into a telescope.

Both the Baader Hyperion and Morpheus eyepiece ranges have an unusual design element: they have a 'hidden' M43 thread under the rubber eyecup. This thread allows for the attachment of a Baader M43/T2 Adaptor, which makes it possible for any T2-to-camera adaptor and, therefore, a camera to be attached to the top of the eyepiece. This opens the way for image projection, where light coming through the scope and eyepiece is projected into the camera body for it to be recorded on the sensor, producing a magnified image.

STEVE RICHARDS

▲ The hidden eyepiece thread allows an adaptor to be attached

Extension tubes to alter the amount of magnification are available from Baader, Bresser, Celestron and Svbony. You will also need a T2-to-Canon adaptor for your Ti5 Rebel DSLR.

Steve's top tip

Why do I need counterweights?

An altaz mount moves perfectly, both horizontally and vertically, so the weight of the telescope remains immediately above the mount. However, if you use an equatorial mount, one of the axes – the right ascension (RA) axis – is tilted at an angle to match your latitude. This important change in orientation places the weight of the telescope off to one side of the RA axis. It's therefore necessary to place a counterweight on an extension bar on the opposite side of the RA axis to exactly balance the weight of the telescope and stop it from rotating downwards under the effect of gravity.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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▸ Star' as it is in the constellation of Canis Majoris, the Big Dog. **– *Ed.***

Waiting for his ball

This is my dog 'Pickle' (pictured, below) patiently waiting for Canis Minor, the Lesser Dog to appear! Pickle is a Sprocker, a Springer-Cocker cross and he particularly likes to accompany me when I am observing from our drive.

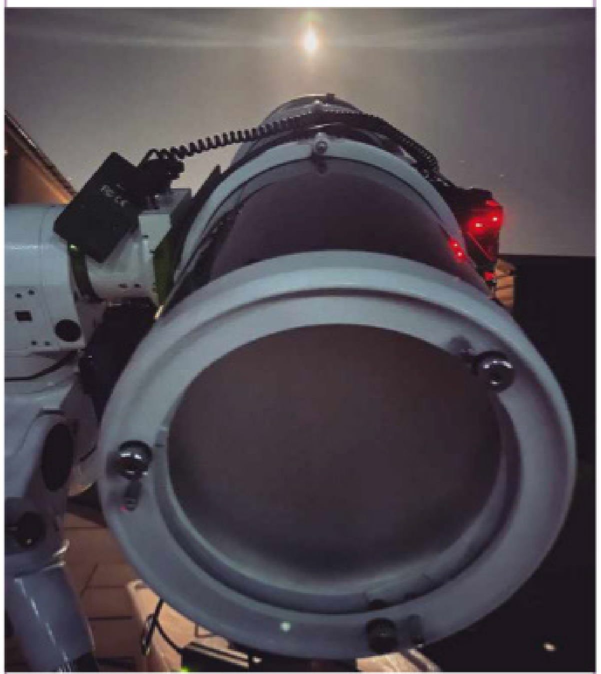
Pickle's favourite thing is a tennis ball and since he saw a full Moon, he has been convinced it is one in the sky – but out of reach for reasons he cannot fathom. I like to think Pickle believes I am trying to get it down for him!

C Paul Lyttle, Moniaive, Scotland

Pickle the dog waits to see Canis Minor

Instagram

scotiaastrouk • 20 Mar 2022



Said a quick 'hello' to our next door neighbour after a successful imaging session...be rude not to...
@bbcskyatnightmag @skywatcherusa @sky_watcher_official @zwoasi

SOCIETY IN FOCUS

In 2020 **Hampshire Astronomical Group** (HAG) celebrated its 60th anniversary. We launched a book and video documenting the dedication of members in constructing our three observatories and creating the training, research and educational programmes run by our volunteers today.

HAG's expertise and scientific credentials were enhanced greatly by the commissioning of its 24-inch Ritchey-Chrétien telescope in 2014. This helps members with their research interests, which include spectroscopy; video and radar detection of meteors; participating in the citizen-science project Hunting Outbursting Young Stars (HOYS); confirming the orbits of near-Earth objects; detecting exoplanets; and general astrophotography.

The COVID-19 lockdowns caused minimal disruption to our weekly talks and monthly lectures, thanks to Zoom keeping members connected and astronomically engaged. We introduced a new digital membership, offering remote participation and, after installing a ventilation system, we began hybrid meetings with members joined by digital attendees.

▲ A 2019 solar spectroscopy session led by Hampshire Astronomical Group's Chair Steve Broadbent

Our educational activities are as popular as ever. The beginner's astronomy course, mentoring sessions with University of Portsmouth students, public open evenings and group visits have all resumed at the observatory. Plus, we supported the University's virtual stargazing event and the South Downs Dark Skies Festival.

Finally, spring 2022 sees our monthly public lectures returning to Clanfield Memorial Hall with an exciting speaker line-up, including Professors Jim Al-Khalili and Chris Lintott, open to live and digital audiences. Who knows what the next 60 years will bring!

Sarah O'Brien-Twohig,
HAG Publicity Coordinator
▸ https://hantsastro.org.uk

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Live Exmoor stargazing

Minehead, Somerset, 3 May, 7:30pm

From novices to experts, all are welcome to join Exmoor StarGazers for their monthly meet-up and (weather permitting) stargazing session at the Kildare Lodge Hotel. Free. **www.facebook.com/ExmoorStargazers**

Online Why does the Pope have an Observatory?

9 May, 7pm

As part of its 20th anniversary celebration, the Society for the History of Astronomy hosts Brother Guy Consolmagno, director of the Vatican Observatory, as he traces how astronomy, the Church and politics have collided since the observatory's origins in 1582. For Zoom details contact: **meetings@shastro.org.uk**

Online Space exploration talk

17 May, 1pm

Astronomer Royal Martin Rees looks at the growing role of robotics in the search for life on other planets in this free Royal Astronomical Society public lecture. See **ras.ac.uk/events-and-meetings**

Online The Sky and Ocean Reconnected

18 May, 1pm

This free online seminar explores the historical links between astronomical observatories and maritime exploration, trade and empire-building. To join on Zoom, go to **www.rmg.co.uk/whats-on**

EXMOOR STARGAZERS, BRETT PRESTIGE, NATIONAL SPACE CENTRE X 3

PICK OF THE MONTH

▲ David Bowie's iconic music is showcased with footage of the Moon landings in Leicester

LIVE Bowie: Oddity to Mars

National Space Centre, Leicester, 20 and 21 May

NASA's Apollo Moon landings and the music of David Bowie are brought together this month in a live event at Leicester's National Space Centre as the Sir Patrick Moore planetarium – the UK's largest – plays host to a performance of Bowie's music alongside an immersive 360° full-dome planetarium show.

Bowie's iconic 'Space Oddity' and Ziggy Stardust era was also the time of humanity's first steps on the Moon, and the show features out of this world imagery of the Apollo missions and spectacular sights from the distant Universe. Tickets £17.50. **spacecentre.co.uk/event/bowie-oddity-to-mars**

Online Tour ESO's telescopes

20 May, 9am

Teachers and their students, aged 14–19, can take a virtual tour around some of the world's largest telescopes at the European Southern Observatory's Atacama Desert site in Chile, and learn about the roles of astronomers working there. **bit.ly/3JAYxuE**

Live Stargazing evening

The Observatory Science Centre, Herstmonceux, E Sussex, 21 May, 4:30pm

Spend an afternoon and evening strolling around the indoor and outdoor exhibits and telescopes at this world famous astronomical observatory, and enjoy a planetarium show. Costs £15 per adult, £12 per child, and includes a portion of chips. **www.the-observatory.org**

Live Informal observing

Bettridge Centre, Newtonhill, 24 May, 7pm

Try out telescopes and get advice from members at the Aberdeen Astronomical Society's informal observing evening on the fourth Tuesday of each month. **www.aberdeenastro.org.uk**

FIELD OF VIEW

Poetry in lunar motion

Caroline Burrows spends a month making poetic observations of the Moon

As a poet and a writer, I love the Moon and its associated vocabulary: words such as 'moonset', 'celestial' and 'lunation'. But my mind struggles with its more scientific aspects: the Moon's haphazard schedule; it only being called a quarter when half of it is visible; and the geometry of its rotation. To better my understanding, I combined science with poetry, writing a verse each night for a lunar month titled 'Between New Moons'.

In the lengthening November nights, I'd check my Moon app and set out on late strolls up Bristol's urban hills in the direction of its azimuth, that's Moon-speak for bearing. I visualised it as a ship circumnavigating Earth, each night the planet having to rotate a bit extra to catch up. That explained why, from my fixed position, the Moon rose later each night.

One evening with a friend, I cycled to Troopers Hill, which provided an uninterrupted ecliptic path overhead and a panorama of city lights glittering below. We watched the Moon's almost half-lit face play hide-and-seek behind clouds, now knowing first quarter was referencing the distance it had travelled on its orbit round our planet.

On nights when sightings weren't possible, I explored the 17th-century map by Riccioli, enamoured by the plains he named as seas divided into good and bad weather.

The Sea of Clouds, the Sea of Rains
Swirled into an Ocean of Storms.
When Moon's calm right-side ebbs and wanes,
What's left works tempestuous forms.

The Moon revealed other ways science and literature have crossed paths. Throughout history, selenographers have named craters after astronomers, scientists and philosophers. There is one for Copernicus, whom I knew from Brecht's play *Life of Galileo*. I'd studied *Poetics* by Aristotle, who is up there, too. I was overjoyed to see Haworth, but discovered it was for a Nobel chemist not the Brontë sisters. Nevertheless, for me, there was now a link to *Wuthering Heights* near the lunar south pole.

By week three, I was becoming obsessed. I'm a night owl, so the Moon appearing around 1am wasn't a problem. In the garden I kept setting off a security light. Fortunately, my neighbours didn't see me standing on a plastic chair, my binoculars pointed in their direction because the last quarter Moon was above their roof.

ILLUSTRATION: LYDIA MALTBY

▲ **Famous faces and places: knowledge of Moon craters' names can be gained from unusual sources**

Caroline Burrows is a professional poet and writer based in Bristol, who's been featured on BBC Radio 4. Read more of her 'Between New Moons' verses on social media: @VerseCycle

The week of the waning crescent coincided with 'Museum of the Moon', a 7m-diameter replica of the lunar globe installed as an inflatable artwork at Bath Abbey. I got up close to Grimaldi, a crater I'd peered at nights before. Back home, I caught up on *Who Do You Think You Are*?, with Judi Dench being told she was related to Tycho Brahe. I knew that name!

Tycho, the Moon's southern crater,
Has impact rays in multitude.
To this one Earthly spectator,
They look like lines of longitude.

Then, with the lunar month ending, Bristol's planetarium showed *Apollo 11* and I watched the Moon landing. In astronomy, everything lining up like that would be called a syzygy. In literary terms, it was poetic.

Look for the magnificent Sombrero Galaxy, M104, in the constellation of Virgo, the Virgin this spring

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

Welcome to GALAXY SEASON

For many astronomers, springtime means one thing – galaxies. **Stuart Atkinson** reveals this season's deep-sky highlights

When I was at school I was fascinated by space, but also by the weather. I devoured the library's science books, describing how the weather changed with the seasons. Those books depicted the seasons with delightfully sentimental illustrations. Spring was represented with lambs gambolling in fields of wild flowers; summer was a beach scene with children making sandcastles; autumn showed a child in a raincoat and wellies splashing through puddles; winter was a snowman, surrounded by a family dressed in scarves and gloves and a robin in a nearby holly tree. Eventually, I learned that the night sky has seasons too: as the months pass, amateur astronomers look at different celestial objects at different times of the year. In summer, we observe the misty band of the Milky Way and noctilucent clouds (NLCs). In autumn, we gaze again at the star-frothed spiral of the Andromeda Galaxy, M31, and frosty winter nights belong to Orion, its nebulae and glittering star clusters.

Spring is 'galaxy season', when telescopes swing towards a selection of constellations, hunting for the faraway galaxies that lie within them. Over the following pages we'll look at why springtime is a boon for galaxy-hunters, and highlight three constellations and a nearby galaxy cluster that contain some of the best galactic targets to point your telescope at over the coming weeks and months. ▸

Why is springtime galaxy season?

Our planet's journey around the Sun provides us with an ever-changing view of the Universe

How can one time of year be better for observing galaxies than others? It's all to do with Earth's position in its orbit. During summer, we enjoy our best views of the Milky Way because that's when the Sun is farthest in our sky from the constellations that contain the brightest and most densely star-packed areas. In spring, Earth's position gives us our best view of the constellations that contain the most galaxies. This includes galactic clusters, where it's possible to observe several galaxies at the same time.

You'll get the most out of galaxy season with a telescope

Many observers look forward to spring because, compared to naked-eye star clusters like the Pleiades, M45, or bright nebulae such as the Orion Nebula, M42, the season's galaxies are challenging yet rewarding targets. Although some are big and bright enough to be seen through binoculars, most require a good telescope to view them at their best. Larger instruments under dark skies reveal the spiral arms and cores of a few, while through smaller telescopes most will resemble small grey smudges. For most observers, galaxy season is all about observing those smears through a telescope and being awed by these distant, colossal structures.

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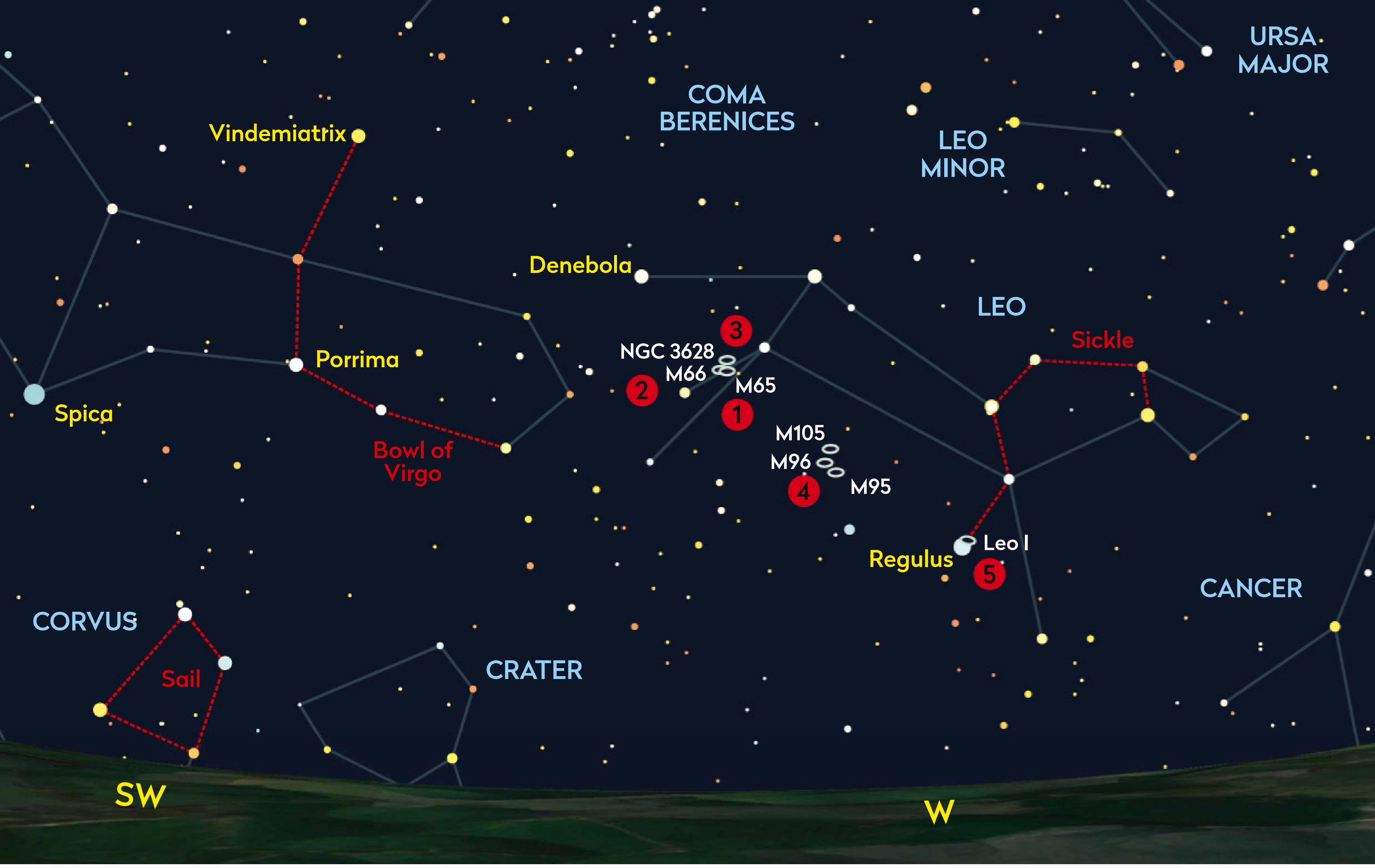
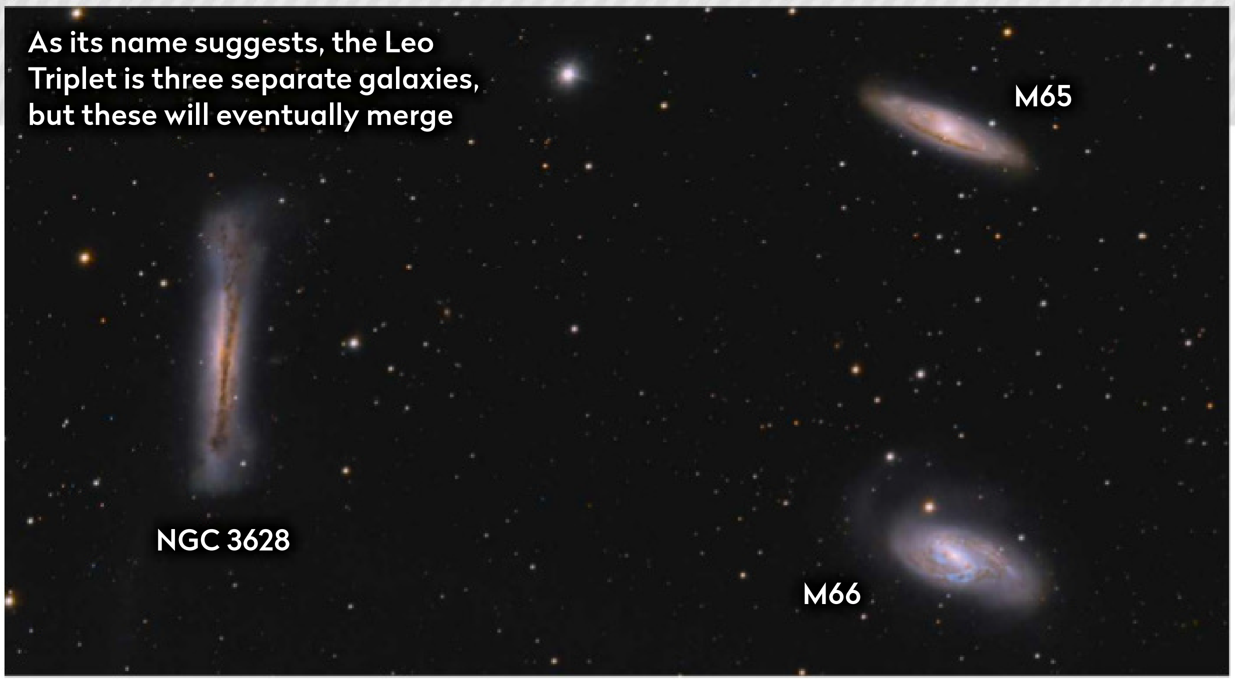


LEO

Sphinx-shaped Leo, the Lion is famous for its Sickle asterism, a pattern of six stars, including first-magnitude Regulus (Alpha (α) Leonis), that form the shape of a curved blade, although others see it as a back-to-front question mark. It also contains fascinating galaxies, including...



As its name suggests, the Leo Triplet is three separate galaxies, but these will eventually merge

1. M65

With a magnitude of +10.3, this spiral galaxy is 35 million lightyears away and is one member of the famous 'Leo Triplet', a trio of galaxies all visible in the same telescopic field of view. High magnifications reveal its tightly wound spiral arms and bright centre. It has a diameter of about 90,000 lightyears.

2. M66

The brightest of the Leo Triplet, this barred spiral galaxy's arms are among the brightest of any galaxy's. Shining at mag. +8.9, it's just visible through binoculars on a dark, Moon-free night, but you'll need a telescope to see its mottled arms. M66 lies 35 million lightyears away.

3. NGC 3628 – THE HAMBURGER GALAXY

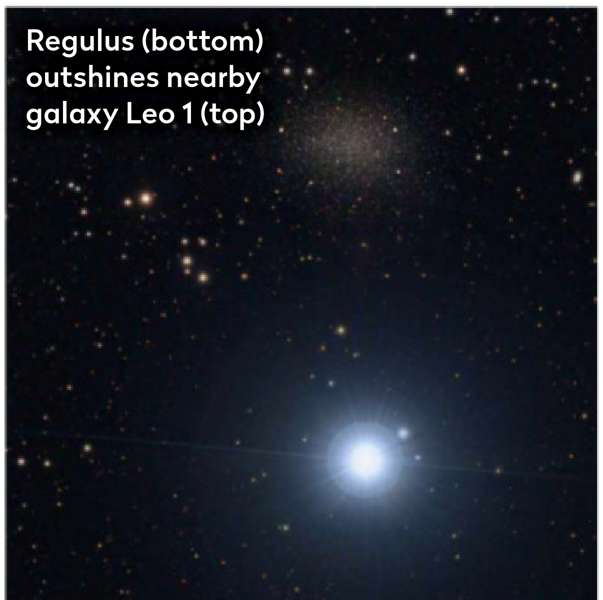
The faintest of the Leo Triplet, this galaxy appears edge-on from our perspective. It's a spiral galaxy with a broad, dark central dust lane, visible through large telescopes on nights of very good seeing.

4. M96

This spiral galaxy has a central dark dust lane crossing a very bright core. At mag. +10.1, it's visible in small telescopes, but with a larger instrument you'll also be able to see the faint spiral arm that curves away from it to the southeast.

5. LEO 1

If you fancy a challenge, this is it! Almost lost in the glare of nearby Regulus, Leo 1 is small, very diffuse and faint. Its magnitude of +11.2 means that only owners of large telescopes blessed with clear skies and no light pollution will see it clearly. Even then it will appear as a small smear of light in the eyepiece. But that smear of light is a satellite galaxy of our own, just like the much larger and brighter Magellanic Clouds that grace the southern sky. This makes it a must-see this galaxy season.


Regulus (bottom) outshines nearby galaxy Leo 1 (top)

COMA BERENICES

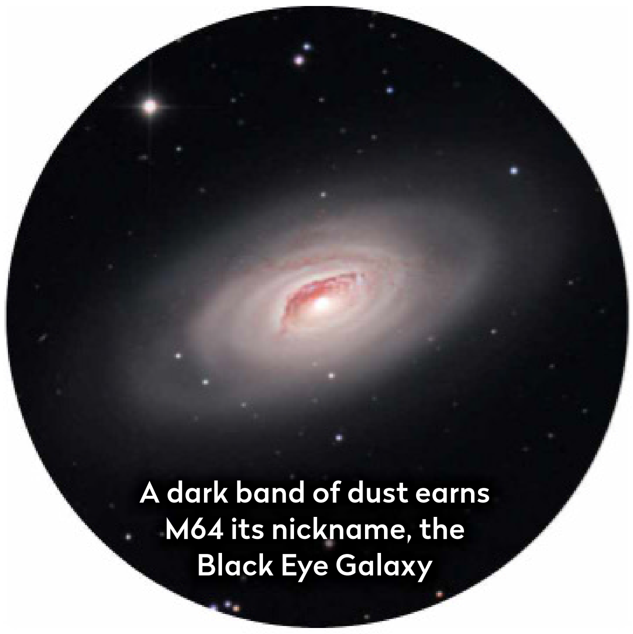
Coma Berenices – or Berenice's hair – is one of those constellations that looks absolutely nothing like the object it's supposed to represent. You'd need the imagination of Steven Spielberg to see 'maiden's hair' when you look at this spattering of faint stars between Leo and the Plough. But swing a telescope towards it and you'll see lots of intriguing galaxies, including...

1. M64 – THE BLACK EYE GALAXY

One of the most famous galaxies in the sky, eighth-magnitude M64 is bright enough to see as a small, misty patch in binoculars, but you'll need a telescope to appreciate how it got its strange nickname. Under high magnification you'll see a prominent dark dust lane – discovered by William Herschel – crossing the lower part of its bright central core.

2. NGC 4565 – THE NEEDLE GALAXY

One of the most beautiful galaxies visible during galaxy season, NGC 4565 is around 30 million lightyears away. It's an edge-on spiral and large instruments give wonderful views of its bright, round core and the dark dust lane that crosses it. Many observers have wondered how Charles Messier missed spotting this mag. +9.6 treat, which is often used to illustrate how the Milky Way would appear to an observer on a distant world.



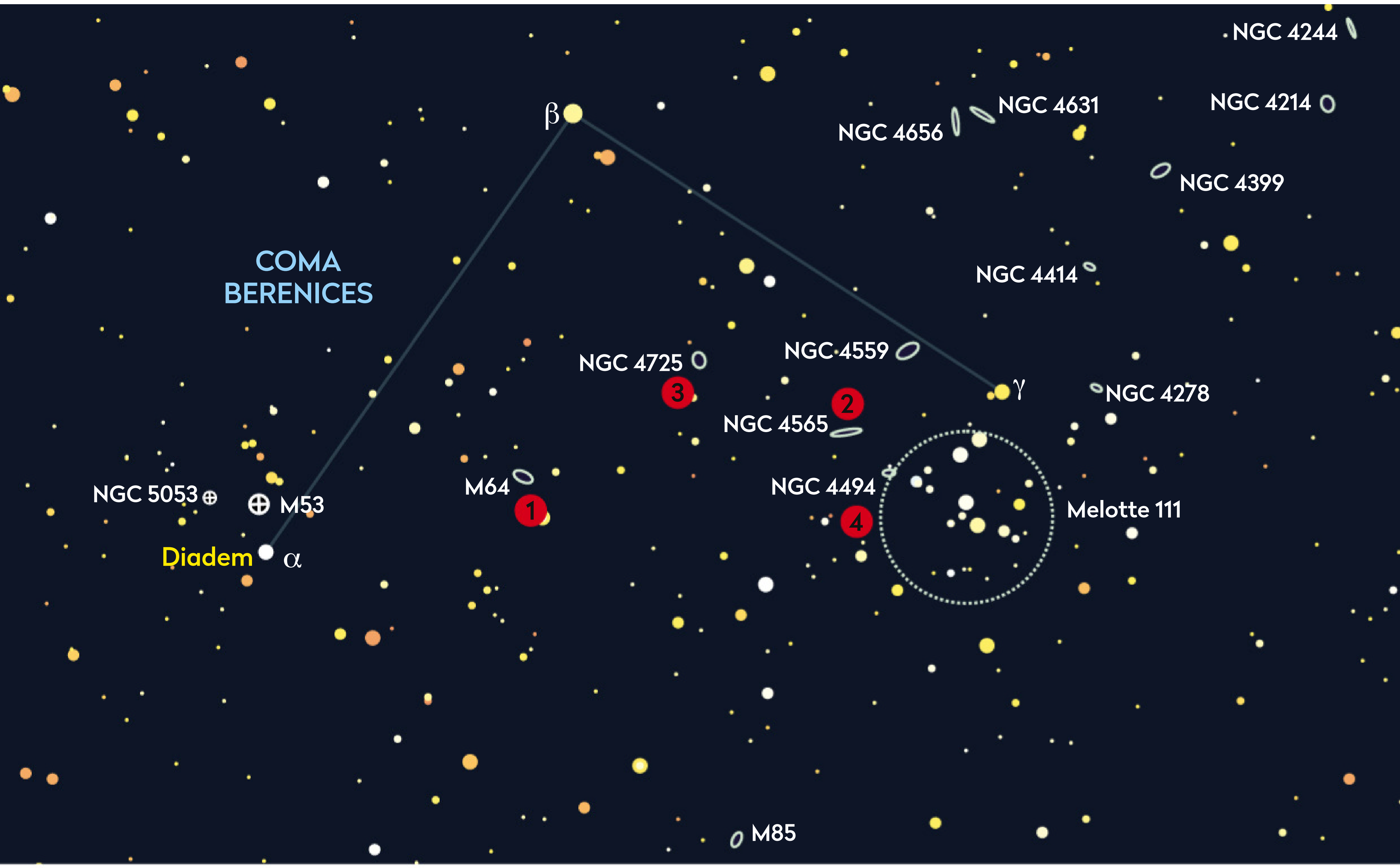
A dark band of dust earns M64 its nickname, the Black Eye Galaxy

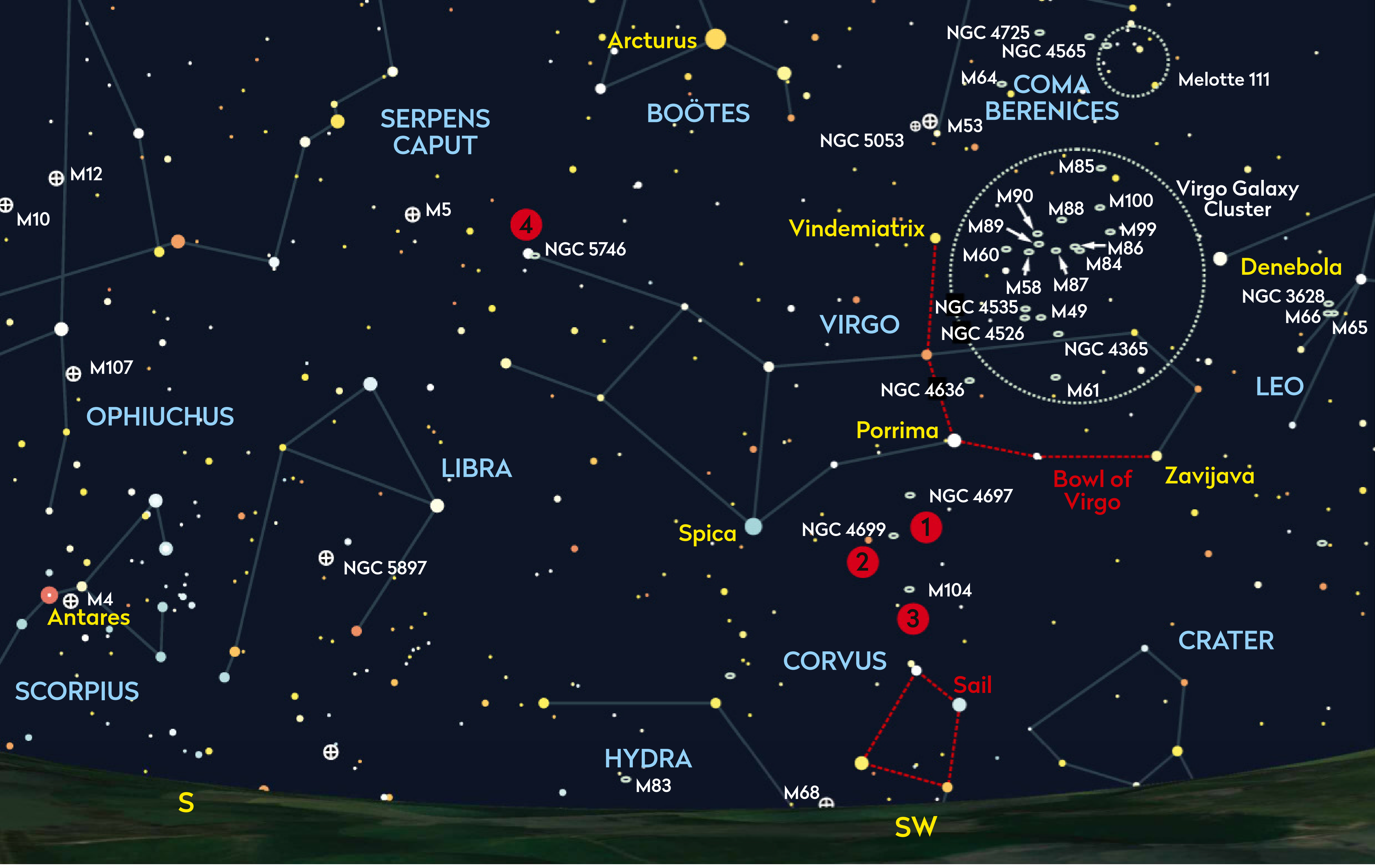
3. NGC 4725

This eighth-magnitude barred spiral galaxy is 39 million lightyears away. Visible in binoculars as a small, oval-shaped smudge, it has been compared to a miniature version of M81. High magnification shows hints of the single spiral arm that curls away from its central bar.

4. NGC 4494

A mag. +9.7 elliptical galaxy, NGC 4494 is relatively unremarkable, visually, but it makes our list because it's a good example of what most galaxies actually look like when seen through a telescope. Galaxies that look like Catherine wheels, with bright, star-frothed spiral arms, are the exception, and the vast majority appear more like little NGC 4494 – a small, faint smudge of pale grey. ▸





VIRGO

Like neighbouring Leo, the constellation of Virgo, the Virgin straddles the ecliptic, so it is often visited by the Moon and planets in Earth's night sky. Although Virgo has quite an abstract shape, it contains many galaxies, including some of the best-known in the sky, such as...

1. NGC 4697

This mag. +10.9 elliptical galaxy appears as a misty, flattened disc in a large telescope. Like most ellipticals, it has no outstanding visible features or structures, and really is a hazy ball of pale, ancient stars. Astronomers have detected a huge black hole at its centre, with a mass between 50 and 100 million times greater than our Sun.

2. NGC 4699

This spiral galaxy is 65 million lightyears distant and has a magnitude of +9.4. Large telescopes show it as an almost flower-like object, composed of multiple faint rings and arcs. It is around 85,000 lightyears across and was discovered by William Herschel in 1786.

3. M104 – THE SOMBRERO GALAXY

With a magnitude of +8.0, this famous galaxy can be seen easily through binoculars on a clear, dark night, looking like a small oval patch of grey light. Look at it through a telescope, however, and you'll see why it's compared to a Sombrero hat: it's an edge-on spiral galaxy with a bright and unusually large central bulge that's crossed by a thin, dark dust lane. We now know that a 1 billion solar-mass supermassive black hole lurks at its centre.

▲ NGC 4699's many rings and arc give it the appearance of a flower

▲ A larger telescope is needed to see NGC 5746, which is edge-on from our viewpoint

4. NGC 5746

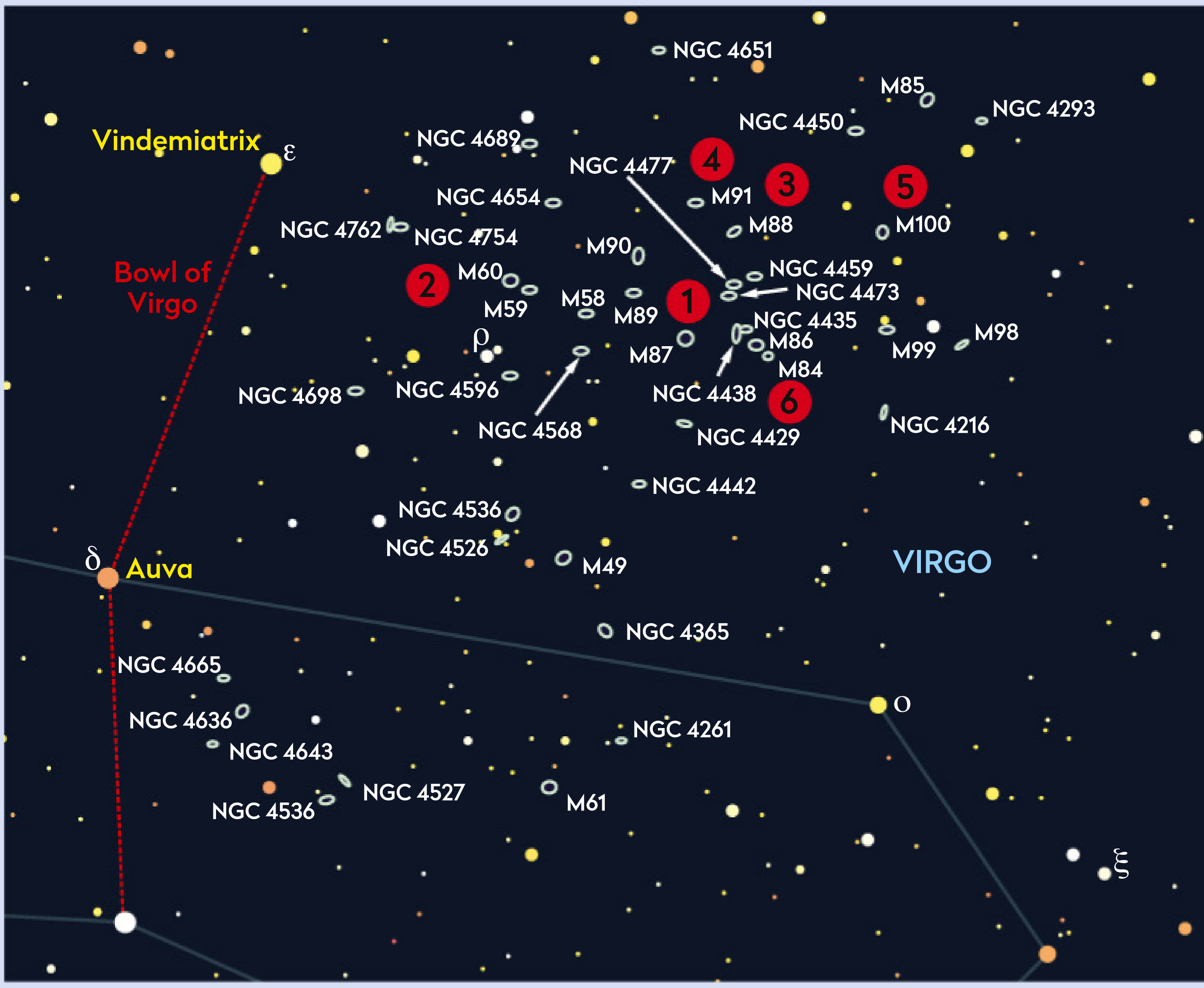
NGC 5746 is a typical edge-on spiral galaxy. It has a bright central bulge that's bisected by a dark lane of dust. With a magnitude of +10.0, it's too faint to be seen in binoculars and is little more than a faint misty line in small telescopes, making it a target that's best suited to larger instruments.

CHARTS BY PETE LAWRENCE, RICK J/WWW.CLOUDYNIGHTS.COM, OLIVER SCHNEIDER/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM

The Virgo Cluster

Take a closer look at the constellation of Virgo and you'll spot this wonderful cluster of galaxies full of deep-sky treats

Just as stars form into clusters, so galaxies do too. These truly enormous structures, millions of lightyears across, contain vast numbers of galaxies of all shapes and sizes, moving through space together like snowflakes in a blizzard. There are several such clusters, each containing many deep-sky objects, but the Virgo Cluster, a spray of more than a thousand galaxies, is in a class of its own.



1. M87 – VIRGO A

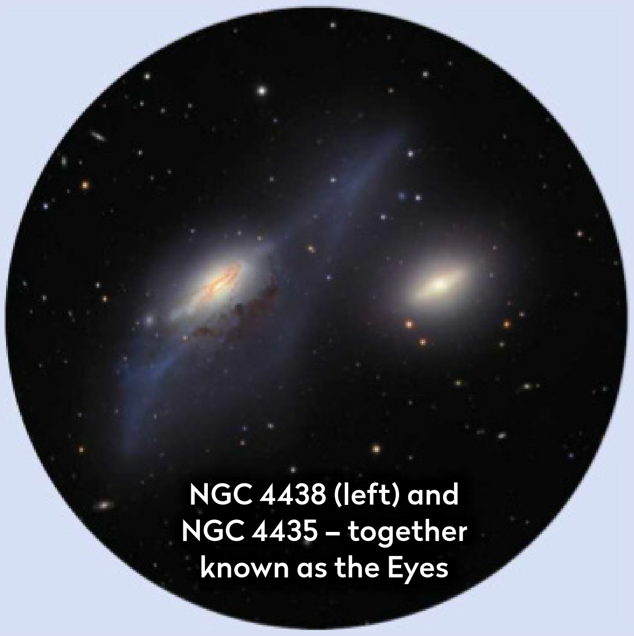
The brightest member of the Virgo Cluster, this elliptical galaxy floats at a distance of 55 million lightyears and has a magnitude of +8.6, making it easily visible through binoculars. With a telescope it will appear as an almost circular hazy patch. Images taken with the Hubble Space Telescope show a pair of high-energy jets shooting out of M87 like lighthouse beams. M87 is a huge galaxy, perhaps as much as half a million lightyears wide, and is surrounded by more than 12,000 globular clusters, compared to the 200 or so that orbit the Milky Way.

2. M60

A true monster of a galaxy, this giant elliptical contains around a trillion stars. Shining at mag. +9.8, it's visible as a tiny smudge through binoculars, but large telescopes will clearly reveal its round shape and also its close visual companion, the spiral galaxy NGC 4647, which is about two-thirds the size of M60. Discovered in 1779 by the German astronomer Johann Gottfried Köhler, M60 lies 54 million lightyears away from Earth.

3. M88

Mag. +9.3 M88 is a giant spiral galaxy. Through a telescope it appears as a misty oval smudge, which some observers think resembles a shrunken version of M31, the Andromeda Galaxy. Large instruments reveal hints of mottling within this compact spiral's tightly curved arms. Although it is part of the Virgo Cluster, it's located in nearby Coma Berenices.



NGC 4438 (left) and NGC 4435 – together known as the Eyes

4. M91

This 11th magnitude galaxy is one of the faintest object in Messier's catalogue, and is 60 million lightyears away. It's a beautiful sight in a large scope, with two spiral arms curving away from its central bar, but you'll only see those with high magnification under a truly dark sky. It's also located in Coma Berenices.

5. M100

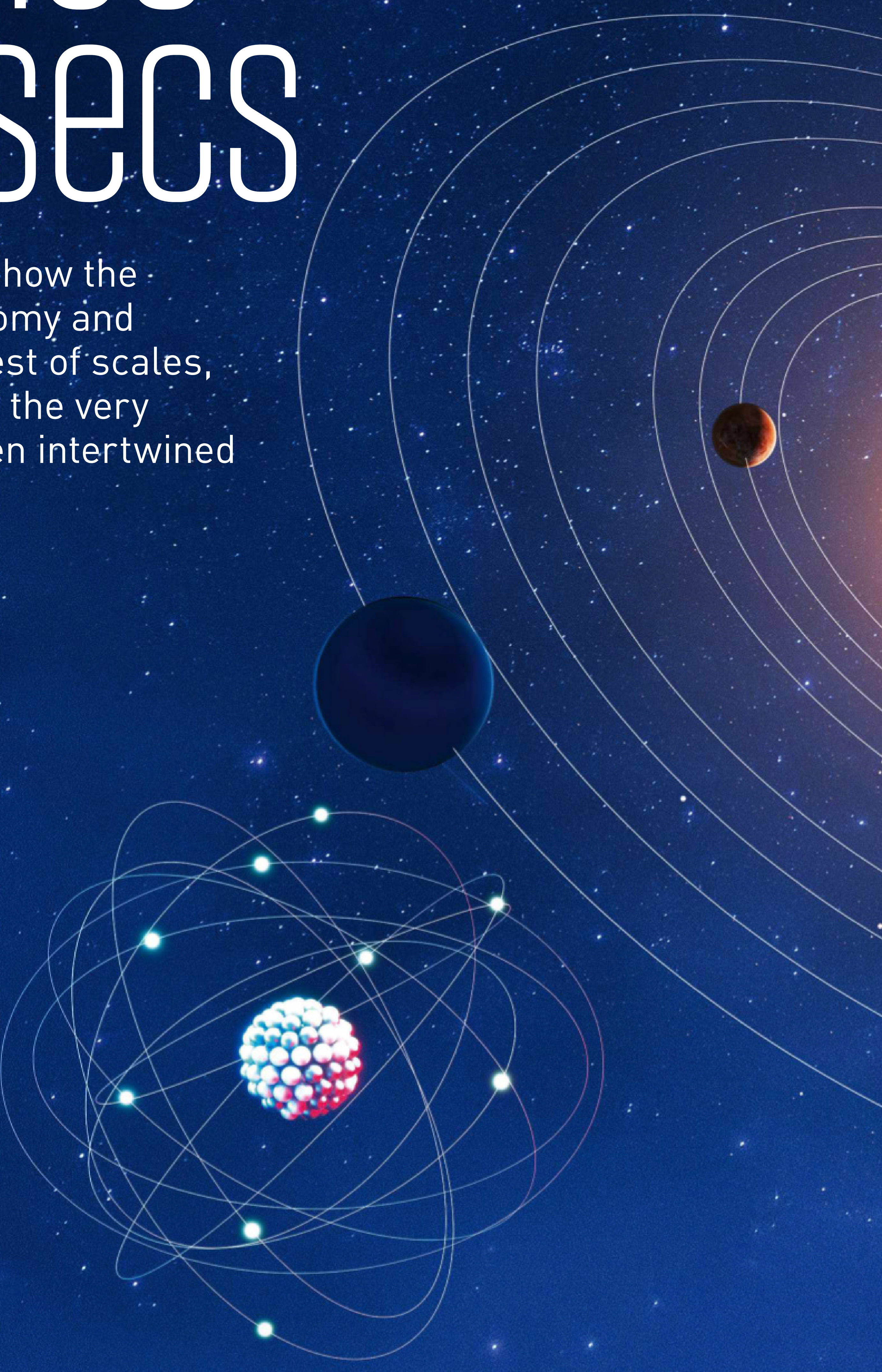
Another beautiful galaxy, M100 has a magnitude of +9.3 and is 52 million lightyears away. Small telescopes show its bright centre and oval shape, while larger instruments reveal tantalising hints of its tight spiral arms.

6. NGC 4438/NGC 4435

This close pair of spiral galaxies was nicknamed The Eyes by LS Copeland, who thought it looked like a pair of eyes staring back at him from the depths of space. Together, they form part of the Markarian's Chain asterism, a trail of galaxies that meanders across the Coma Berenices/Virgo border. At mag. +10.6, NGC 4438 is the fainter of the pair, almost a magnitude fainter than its close neighbour NGC 4435.

From particles to parsecs

Toby Friend considers how the development of astronomy and cosmology on the largest of scales, and particle physics on the very smallest, has often been intertwined



At a glance, physics can seem a radically unfocused discipline. In a single research department you'll find particle physicists investigating the smallest and most ubiquitous objects we know of, like quarks, leptons and bosons. But you'll also find astronomers (including astrophysicists and cosmologists) investigating the largest and most distant things that we know of, like galaxies, nebulae and black holes. No other science comes close to matching interests on such a range of scales. So why do both extremes count within the remit of doing physics?

One suggestion is that physicists are interested in the small and big, the near and far, just because they are interested in everything. At least that's what the many physicists trying to find a 'grand unifying theory of everything' might tell you. But the notion of 'everything' in this context can't really mean everything we might possibly want a scientific theory for. Physicists do not, for example, aspire to theorise about the zebra population of the Serengeti or about the rock strata in the Grand Canyon. Those phenomena are within the remit of ecology and geology, not physics. ▸

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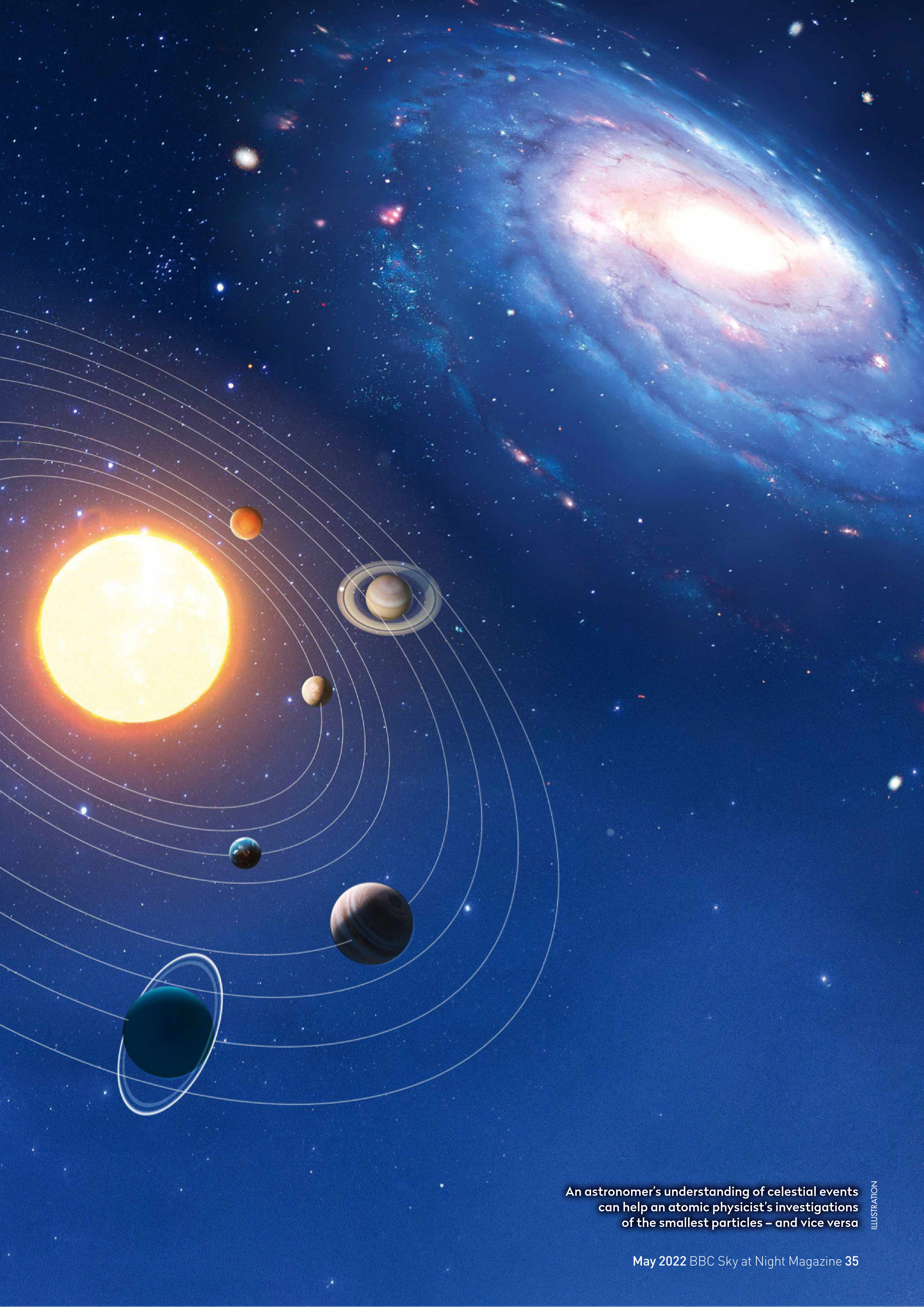


An astronomer's understanding of celestial events can help an atomic physicist's investigations of the smallest particles – and vice versa

ILLUSTRATION

▲ **Tycho Brahe's Planisphere, here shown in a 1660 engraving, presented a heliocentric model of the Universe**

▸ The search by physicists for a theory of everything is really a quest for a theory of the behaviour of the constituents of everything. That explains the continuing interest by physicists in the ever smaller, but why do planets and stars remain of interest? The reason, I suggest, is that the investigation of the far away big stuff is often of benefit to our ability to theorise about the nearby small stuff, and vice versa.

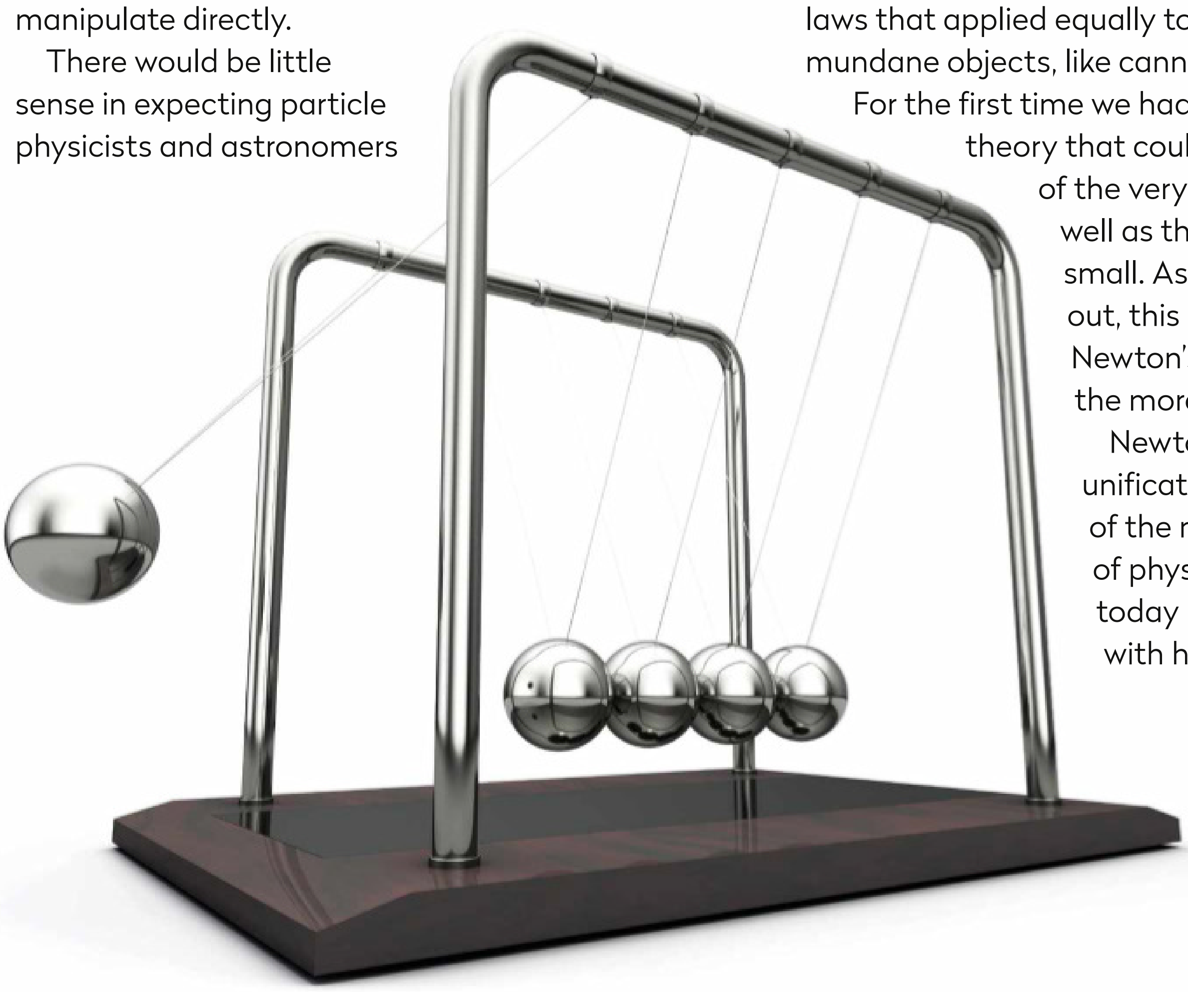
A division of labour

It wasn't always like that, however, as astronomy was once entirely disconnected from the most learned proclamations about the workings of things on Earth. For early Sumerians and Mesopotamians there was sense in such a division of labour: while Earth was inhabited by fallible humans and brute beasts, the heavens were reserved for the gods. Later, Greek mythologies spoke of a special air, or 'aether', breathed by the gods in their celestial realm yet unattainable for the rest of us. This unique substance eventually found its way into genuine speculation by way of Aristotle, who hypothesised about a fifth element to be contrasted with the more homely substances of earth, wind, fire and water. Crucially for Aristotle, this fifth element did not obey the same laws of motion as the material things we can manipulate directly.

There would be little sense in expecting particle physicists and astronomers to share corridors if all this were true. But things changed. The history of how the motions of the planets were brought within the scope of influence of Earthly mechanical laws is rightly one of the most celebrated achievements in science. A first major step came from the careful astrometrical charts of Tycho Brahe. These motivated Brahe's assistant, Johannes Kepler, to publicly question the perfection of the celestial realm by suggesting that the planets, including Earth itself, moved in ellipses around the Sun.

With the influence of more precise astronomical observations, Newton found it possible to further domesticate the motions of celestial bodies using laws that applied equally to the trajectories of mundane objects, like cannonballs and pendulums. For the first time we had a single quantitative theory that could describe the motions of the very distant and large, as well as the very proximal and small. As philosophers like to point out, this unifying capability of Newton's theory made it all the more believable.

Newton's achievement in unification was specifically one of the motion, or 'mechanics', of physical objects. But physics today is not just concerned with how things move. It is



◂ **Newton's cradle: by refining universal laws of motion, Isaac Newton could apply them to celestial bodies as well as pendulums**

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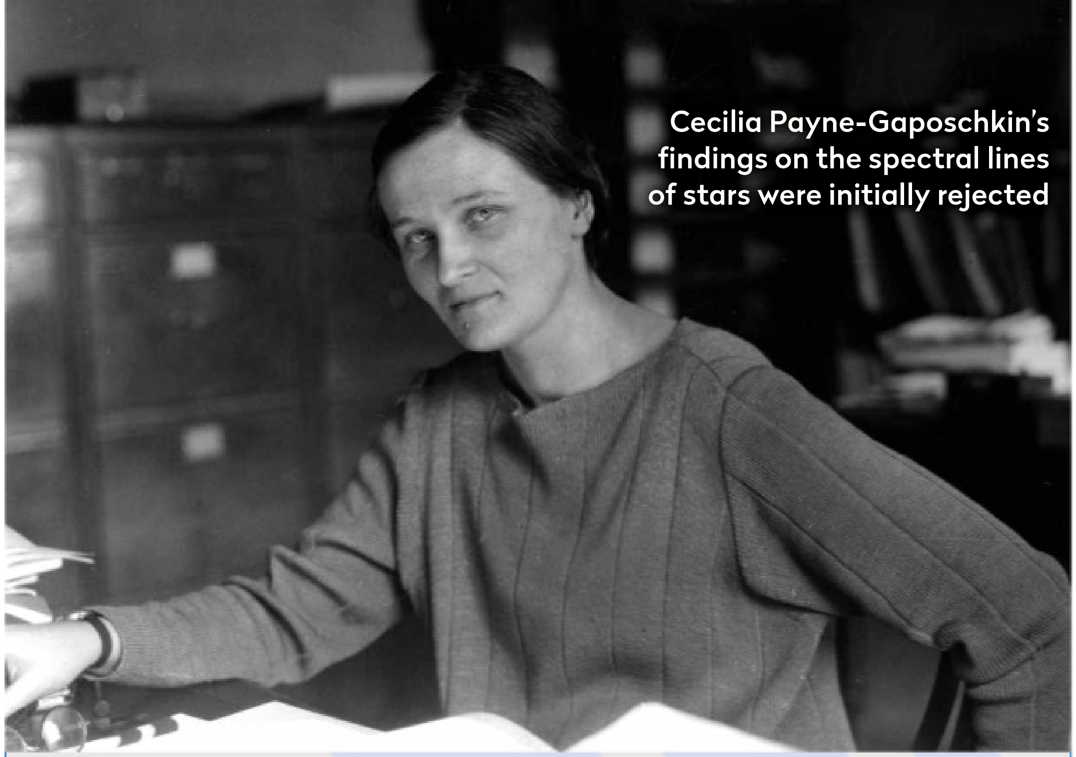


Cecilia Payne-Gaposchkin's findings on the spectral lines of stars were initially rejected

Star credentials

A British-American astronomer who helped uncover what stars are made of

The consensus that the Sun and stars shared a similar composition to Earth became so entrenched in astronomy that it was difficult to overcome. In 1925, Cecilia Payne-Gaposchkin submitted her doctoral thesis arguing that hydrogen and helium in the Sun and variable stars was significantly more abundant than on Earth. Her findings showed that hydrogen in particular was by far the dominant known element of the Universe.

Her demonstration employed an equation that had recently been derived by Meghnad Saha, to show that much of the variation in spectral lines from the stars could be attributed to their temperature rather than their composition. At the time her conclusion was rejected by prominent astronomers like Howard Norris Russell, due to its contradiction with received wisdom.

However, it only took a few years before Payne-Gaposchkin's claims were vindicated and her PhD thesis was hailed as "the most brilliant… ever written in astronomy". She went on to become the first woman to receive the Henry Norris Russell prize from the American Astronomical Society in 1976.

concerned also with the behaviour of light, energy conservation, the sources of force, the basic constituents of matter and the structure of space and time. In one way or another, astronomy has informed and been informed by all these areas.

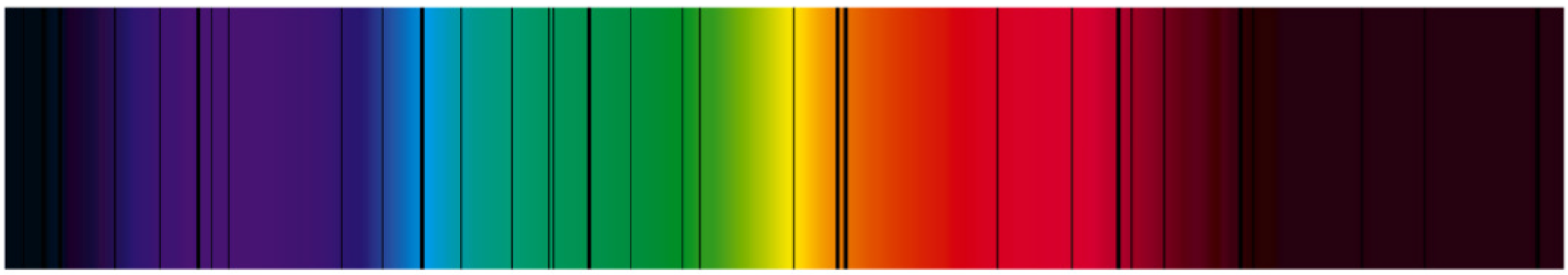
Consider, for instance, the birth of astrophysics. Some 200 years after Newton's mechanics came on the scene it became widely speculated among scientists that the planets and stars might not only move like things on Earth, they might also be composed of similar stuff too. This was suggested by the fact that the spectrum of light which radiated from the Sun lacked certain wavelengths — the so-called 'Fraunhofer lines'. Curiously, many of these omissions from the spectrum corresponded to the wavelengths that were absorbed and radiated by known gases under a Bunsen burner flame in scientists' laboratories. In particular, hydrogen and sodium's lines were clearly missing from the Sun's spectra. Employing the newly developed techniques of analytical spectroscopy that he developed with Robert Bunsen, Gustav Kirchhoff surmised that these elements must exist as a gas on the outer surface of the Sun and be absorbing the relevant wavelengths from hotter emissions in the Sun's interior.

This was the first time the composition of a celestial body could be given in terms of substances familiar to us on Earth. Yet that didn't stop astronomers suggesting that the Sun might still have some further, unfamiliar ingredient. In the aftermath of the 1868 solar eclipse, astronomers Pierre Janssen and Norman Lockyer independently worked out that certain wavelengths of light radiated by the Sun had not so far been observed from any known Earthly substances. Lockyer promptly proposed a new element only to be found beyond Earth, which he gave the name 'helium', after the Greek 'helios' meaning Sun. By that time, however, it was becoming less plausible to suggest a significant divide between the physics of Earth and of the stars. Helium's extraterrestrial credentials made its existence somewhat controversial.

Helium takes its place

So helium was left out of early periodic tables of the elements. It was only after it was eventually found on Earth, some 27 years later, that it was seen as necessary to accommodate the element in theory. However, this didn't prove so straightforward since the periodic table of elements was largely organised according to the reactivity of elements, and helium didn't seem to react with much. The solution was to propose an eighth group of elements, the 'noble gases', with helium taking the top spot. Impressively, a substance first discovered far away in the heavens was now at the forefront of guiding the science of the local environment.

Following the discovery of helium on Earth there became an even stronger rationale for thinking the ▸



▲ 'Fraunhofer lines', shown here as black lines on the solar spectrum, give scientists clues about the absorption of light by chemical elements

▸ composition of celestial matter was likely to be of a similar kind to Earthly matter. Physics as we know it today was starting to take root and with it a growing consensus towards the end of the 19th century that a small group of physical laws might describe all of the Universe's phenomena. As a consequence it began to be seen as totally acceptable to use theories about the subatomic to inform our theories of the astronomical and vice versa.

One of the biggest developments in astronomy has been the discovery of new kinds of celestial entities

Discovering new entities

One of the biggest developments in astronomy since then has been the discovery of new kinds of celestial entities. Neutron stars and black holes are the most dense objects in the Universe and have an enormous impact on surrounding nebulae. But the hypothesis of their existence came from the development of theories designed to probe the very smallest things known to science.

The new quantum theory, developed in the 1920s and 1930s, predicted that electrons can only occupy certain discrete and distinct energy states in an atom. This implies that when a cluster of particles are densely packed, they will resist further packing by requiring some particles to enter higher energy states. The resulting matter is very hot and very dense, but something with even greater density can be achieved if the forces of attraction among particles are overwhelming.

However, it is not just any cluster of particles that will have sufficient forces of attraction. It was quickly realised that if some stars are massive enough (specifically, above the Chandrasekhar limit of around 1.4 solar masses, the theoretical maximum mass of a stable white dwarf star) then their own gravitational forces will be sufficient for further collapse. Moreover, depending on how massive such a star is after it has gone supernova, its continuing collapse into an even more dense state can result in a neutron star (including pulsars and magnetars) or even a black hole, from which not even light can escape. The latter object was a controversial idea, but astronomers were confident that the new quantum mechanics would apply at large enough scales to validate the prediction. As a consequence, neutron stars and black holes are nowadays familiar features of astronomical observations.

Important theoretical interpretations have also gone from the big to the small. Perhaps the most impressive example of this comes from the observation by astronomers that the velocities of stars in the Milky Way (and, it turns out, other galaxies) can only be explained within the known laws of gravitation if a significant portion of that matter is hidden from view. 'Dark matter', as it has come to be known, defies even our most up-to-date and robust classificatory systems of the subatomic.

The hypothesis of the existence of black holes started with theories designed to probe the smallest things known to science

ILLUSTRATION

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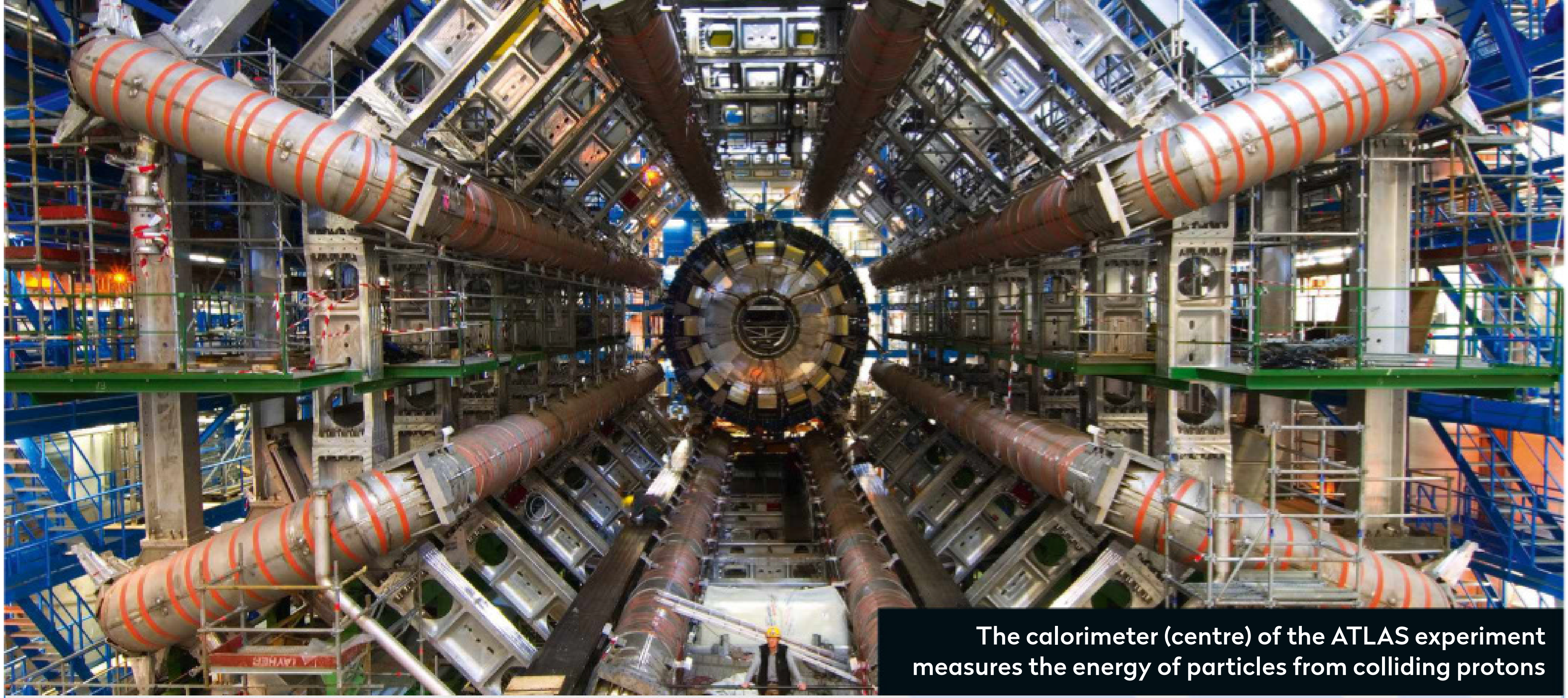

The calorimeter (centre) of the ATLAS experiment measures the energy of particles from colliding protons

Producing particles

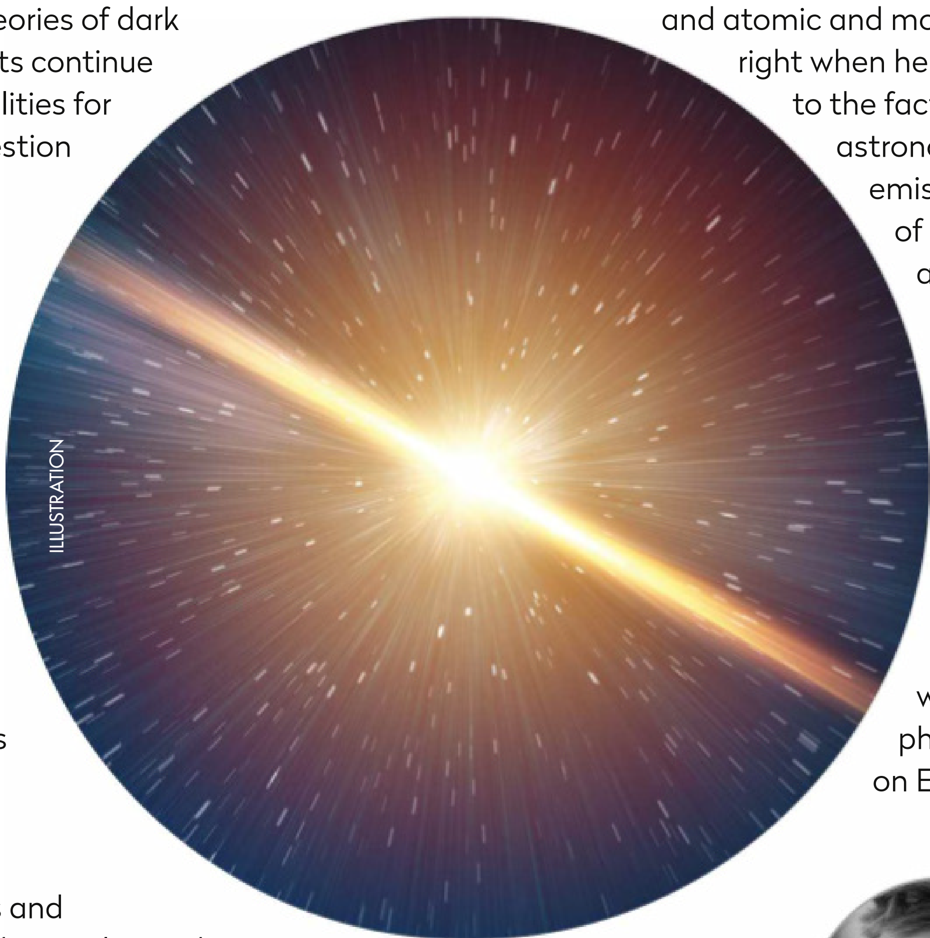
Particle accelerators recreate the Universe's extreme environments

Physicists don't just gather data from the stars. Particle accelerators also feature big in modern experimentation. These often have a toroidal shape, looping particles round and round, boosting their energy as they go. The earliest example of such an accelerator was developed in 1930 by Ernest Lawrence and measured only 5 inches (12.7cm) across. The largest to date has a diameter of more than 5 miles (8km)!

By attaching detectors at various points, physicists are able to observe physical events at extraordinary energies. Some experiments have stood out in recent history. The ATLAS experiment at the Large Hadron Collider in Switzerland involves the largest particle detector ever made. It is a cylinder 46m long and 25m in diameter, with 100 million sensors. In 2012, ATLAS was key to confirming the existence of the Higgs field, which is thought to help confer particles with some of their mass. It did this by detecting the particle associated with this field: the Higgs boson. This discovery added more confirmation to the Standard Model (a physicists' default theory of fundamental physics).

But another series of experiments did the opposite. In 2001, physicists at the Brookhaven National Laboratory's accelerator siphoned off a beam of muons (a bit like massive electrons) into a magnetic ring in the hope of establishing a so-called 'g' value. Their results, which were corroborated at Fermilab's accelerator in 2019, indicated that the 'g' value was not what the Standard Model predicted. But because the results are not as statistically significant as they would like, physicists are holding off from saying if they are indicative of a new theory.

(See page 60 for more on how theories of dark matter were developed.) Physicists continue to discuss a wide range of possibilities for how it might turn out. One suggestion is that dark matter comprises Weakly Interacting Massive Particles (WIMPs). Another is that it is made up of axions, a hypothetical low mass particle. In either case, dark matter seems unlikely to appear in the Standard Model of particle physics. And yet we strongly suspect that there is such stuff. Here, then, we have a case in which astronomical observation has led us to think that our theories of the basic constituents of matter need revising.



▲ Particle theories gave astronomers the tools to explain what happens to stars after they have gone supernova

Shared knowledge

The insights that particle physics and astronomy have brought each other explains why practitioners of both areas can expect to meet around the same water cooler. Indeed, many of today's physicists are well versed in both fields. "There is," as physicist A Ravi P Rau explains, "A strong coupling between the subjects of astronomy and atomic and molecular physics." Rau is surely right when he explains that this is partly due to the fact that "our knowledge of the astronomical world is derived from the emission, absorption and scattering of electromagnetic radiation from atoms and molecules. We 'touch' and discern the material content of these distant objects only through such absorptions and emissions." But the coupling of astronomy and atomic physics is also due to the fact that astronomical events provide extreme conditions for atoms and molecules, without which we may never have learned new physics about what goes on here on Earth.


Toby Friend is a philosopher at the University of Bristol, currently researching a project entitled The Metaphysical Unity of Science

In search of the Belt of Venus

Katrin Raynor-Evans looks at what causes the beautiful atmospheric phenomenon that occurs in the sky opposite a sunset or sunrise

On a clear evening, as the Sun is setting in the western sky, you may have noticed a scene reminiscent of a watercolour painting: the eastern horizon becomes awash with a band of pale pinks and blues. If you have, it's likely that you have spotted the Belt of Venus, a subtle atmospheric phenomenon that can be delightful to observe. The name is somewhat misleading, however, because it has nothing to do with the planet Venus, but is instead associated with the girdle or belt worn by the Greek goddess Aphrodite, the Roman counterpart of Venus. Here, we will look at what causes this phenomenon.

As the Sun rises in the east or sets in the west, sunlight reflects off the dense atmosphere in an effect called backscattering, which creates a pink band of light on the opposite horizon to the Sun, above the antisolar point. This pink band is the Belt of Venus. Though it can be viewed at sunrise, the best time to see it is at sunset.

When the Sun is setting in the west, look east to see the Belt, which is visible about 10–20° above the horizon. As Earth rotates, sunlight is unable to reach parts of our atmosphere, and the pink band turns blue towards the horizon. This is Earth's shadow being cast on to the atmosphere, and as the shadow continues to rise, the band becomes arch-shaped and broadens out.

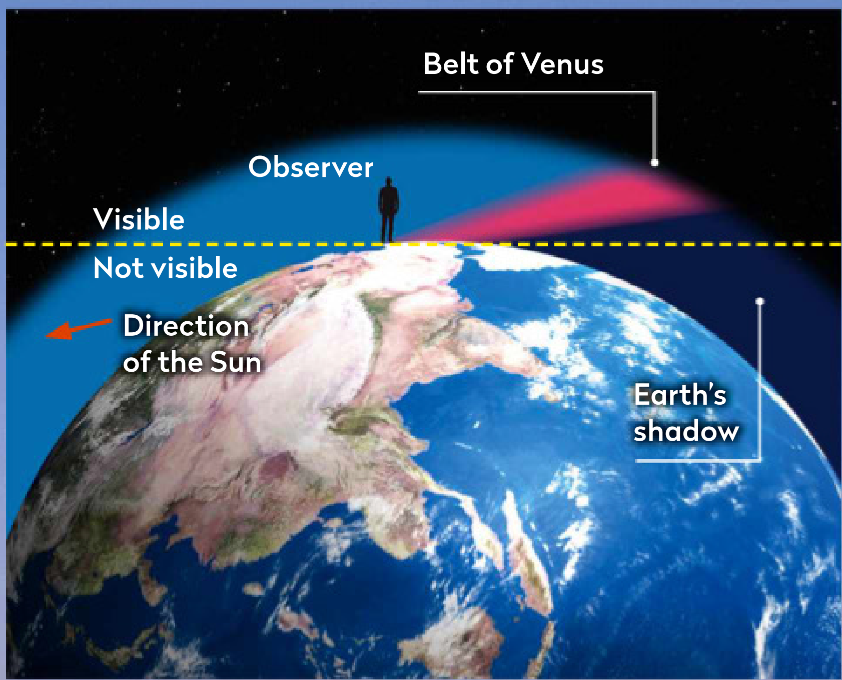
To enjoy the phenomenon, all you need is a clear sky, shortly before sunrise or after sunset, and an unobstructed horizon. The Belt of Venus is a peaceful sight to observe, and it may be visible from a few minutes up to 20 minutes.

Katrin Raynor-Evans is an amateur astronomy writer and Features Editor for the *Society for Popular Astronomy*

WILL GATER

Earth's shadow and the Belt of Venus

When the Sun is below the observer's line of sight, incoming sunlight passes through more atmosphere near the horizon, which causes the observer to see pink wavelengths of light backscattered from the atmosphere. The resulting pink band, the Belt of Venus, appears above Earth's shadow.



▲ Earth's shadow lies at the antisolar point, opposite the Sun. The shadow rises when the Sun sets and sets when the Sun rises

The pink Belt of Venus appears over the Earth's shadow as seen in this wide-field view captured from Somerset, UK

BBC Sky at Night MAGAZINE

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Mary McIntyre

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WATCH ON DEMAND

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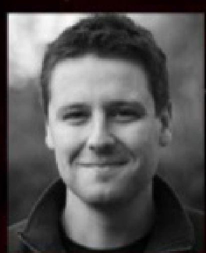
Delving deeper into stargazing: your next telescope setup

Will Gater



Take your observing to the next level! We look at equipment options to help you progress from beginner to intermediate, as well as portable setups.

Thursday 28 April, 7pm BST

Masterclass 3

Home observatories and increasing productivity

Steve Richards

We look at how a permanent observatory or fixed pier can benefit your observing by making sessions under the stars more productive.

Thursday 26 May, 7pm BST

KONSTANTIN VON_POSCHINGER/CCDGUIDE.COM, GETTY X 2, STEVE RICHARDS

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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

PETE LAWRENCE

MAY 2022

TOTAL ECLIPSE OF THE MOON

Watch the Moon pass into Earth's shadow on 16 May, as we get an opportunity to see a total lunar eclipse

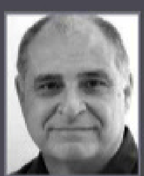
CATCH A SHOOTING STAR

View the peak of the Eta Aquariid meteor shower under a moonless sky

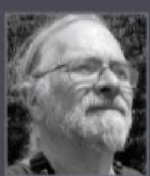
NOCTILUCENT CLOUDS RETURN

The season of 'night-shining' clouds gets underway

About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- ✦ A morning meeting of Jupiter and Venus
- ✦ Comet C/2017 K2 PanSTARRS
- ✦ Minor planet 13 Egeria reaches opposition

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

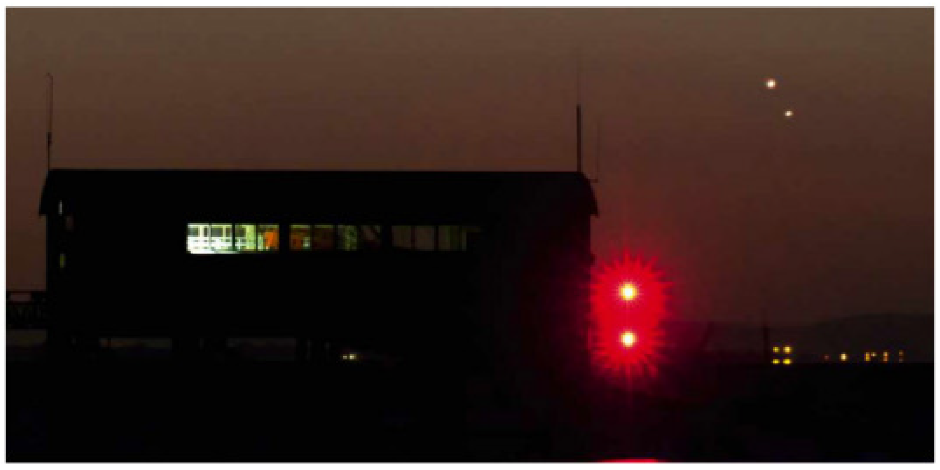
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

MAY HIGHLIGHTS

Your guide to the night sky this month

All Month

Comet C/2017 K2 PanSTARRS is expected to be around ninth magnitude, following a short monthly path in the northeast of Ophiuchus, the Serpent Bearer. The comet is expected to brighten through the month from mag. +9.6 to mag. +8.8.



◀ Sunday 1

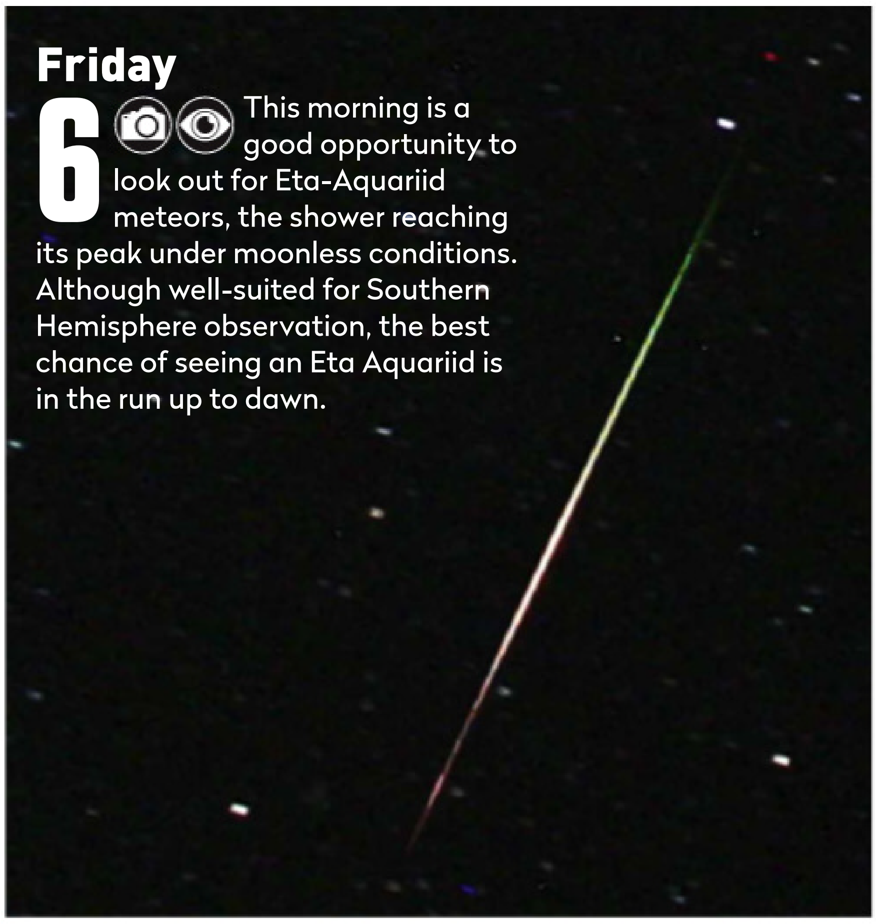
Mag. –2.0 Jupiter lies 22 arcminutes northwest of mag. –4.0 Venus as both planets rise. Spot them from around 05:00 BST (04:00 UT) low above the east horizon.

Wednesday 4

Minor planet 13 Egeria reaches opposition today at mag. +10.0. Egeria will be in Libra, the Scales, less than 1° west-southwest of mag. +2.7 Zubenelgenubi (Alpha (α) Librae), at 01:00 BST (00:00 UT), having passed 20 arcminutes from the star on 1 May.

Thursday 5

Minor planet 18 Melpomene reaches opposition today. Shining at mag. +10.3, Melpomene is currently located in northern Libra.



Friday 6

This morning is a good opportunity to look out for Eta-Aquariid meteors, the shower reaching its peak under moonless conditions. Although well-suited for Southern Hemisphere observation, the best chance of seeing an Eta Aquariid is in the run up to dawn.

Tuesday 10

This evening look for the arc of light known as the Jewelled Handle, extending into the dark of the lunar night. This clair-obscur effect is caused when the peaks of the Jura Mountains around Sinus Iridum catch the lunar dawn's light.

Friday 13

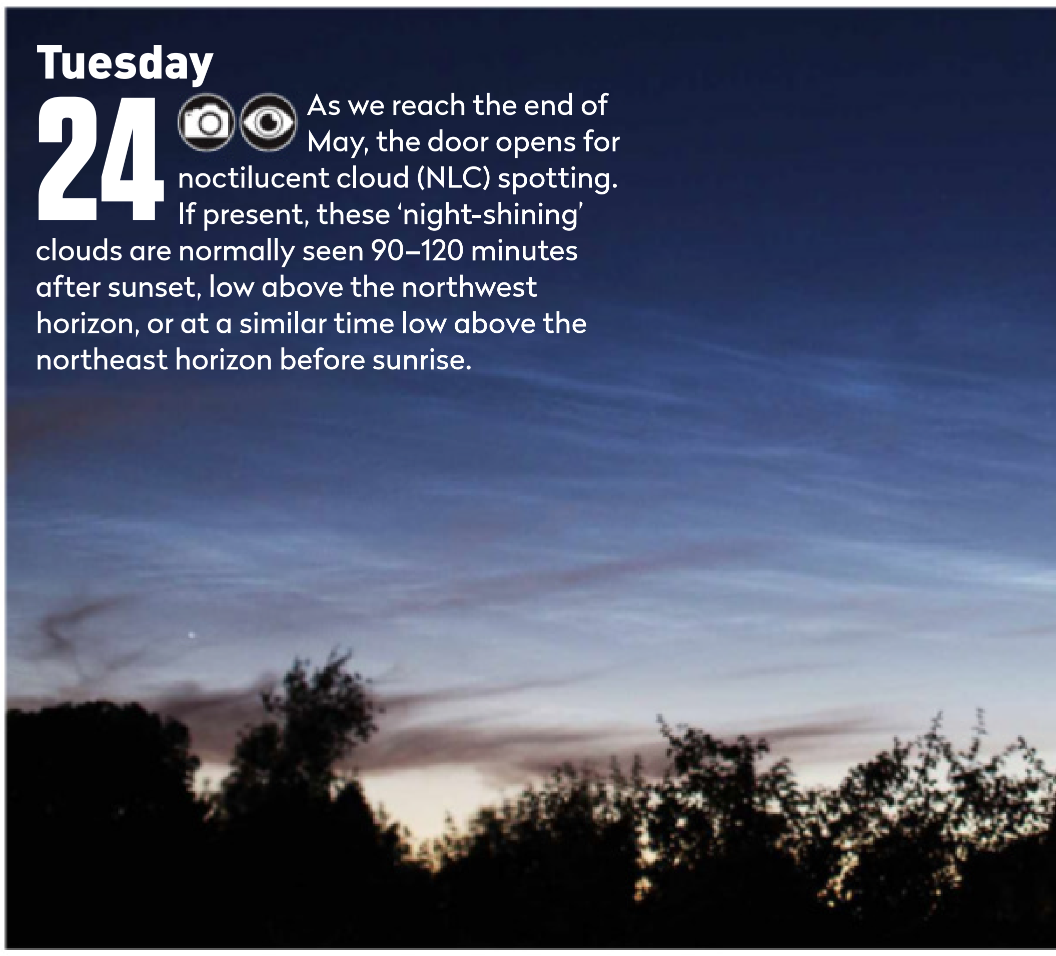
This morning the 87%-lit waxing gibbous Moon will occult the binary star Porrima (Gamma (γ) Virginis). Observe from 01:30 BST to 02:50 BST (00:30 UT to 01:50 UT).

Wednesday 18

Mars and Neptune appear 32 arcminutes apart this morning. Mag. +7.9 Neptune will be extremely hard to see against a brightening morning sky, mag. +0.8 Mars less so. Mag. –2.0 Jupiter lies 6.5° to the east-northeast of Mars.

Sunday 22

The 57%-lit waning gibbous Moon lies 5.8° south of mag. +0.8 Saturn this morning.



Tuesday 24

As we reach the end of May, the door opens for noctilucent cloud (NLC) spotting. If present, these 'night-shining' clouds are normally seen 90–120 minutes after sunset, low above the northwest horizon, or at a similar time low above the northeast horizon before sunrise.

Family stargazing

There's a total lunar eclipse visible during the early morning on Monday 16 May. Plan an early night on 15 May, setting alarm clocks for 03:00 BST. It will pay to have warm clothing and drinks at the ready so you can all be outside and ready to watch the start of the event at 03:27 BST. The Moon will be low above the southwest horizon as the initial partial stage of the eclipse begins and it will remain in this general direction as totality is reached at 04:29 BST. The Moon sets at 05:10 BST so you can all get some more sleep afterwards! **bbc.co.uk/cbeebies/shows/stargazing**

PETE LAWRENCE X 7

◀ Monday

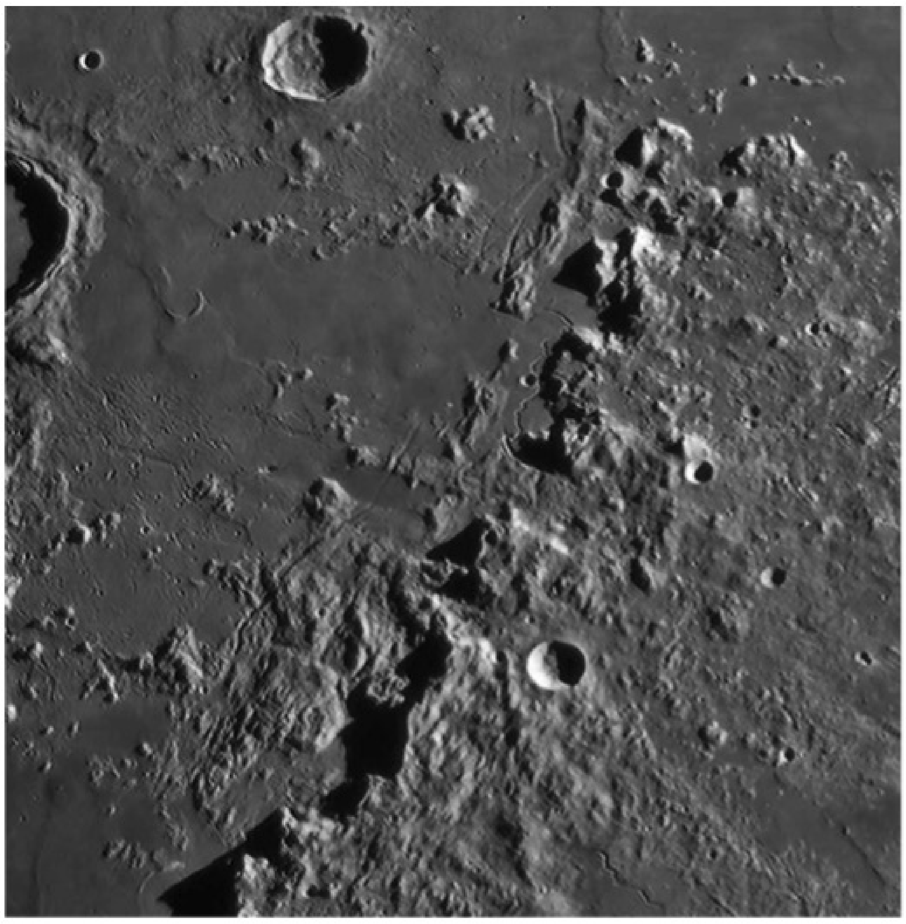
2 If you have a clear, flat northwest horizon, keep an eye out for a slender 3%-lit waxing crescent Moon, 3.2° left of mag. +0.9 Mercury (as seen from the UK). If skies are clear, it may also be possible to spot the Pleiades, 2.8° to the right of Mercury.

Tuesday

3 The Moon is absent at the start and end of May, leaving the sky unaffected by its glare, which is perfect for this month's 'Deep-Sky Tour' on page 56. The darkest skies will be at the start of the month, as the June summer solstice is further away.

Saturday ▶

7 Our 'Moonwatch' target for May is the dramatic Apenninus mountain range, which borders Mare Imbrium. Observing it this evening and over the next couple of days will slowly reveal its intricate beauty. See page 52 for more details.



Monday

16 There's a total lunar eclipse this morning. The Moon enters Earth's penumbral (weak) outer shadow at 02:32 BST (01:32 UT), encountering the darker umbra at 03:27 BST (02:37 UT). Totality begins at 04:29 BST (03:29 UT).

Wednesday

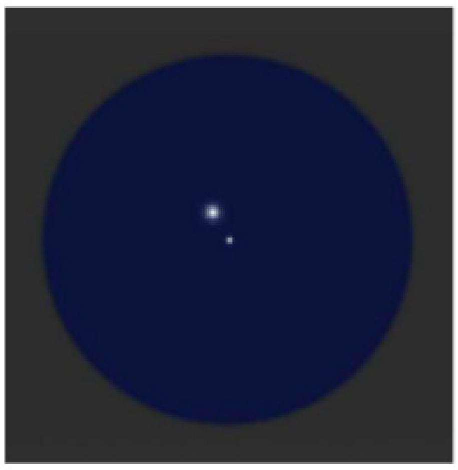
25 Mag. +0.7 Mars, mag. –2.1 Jupiter and a 25%-waning crescent Moon form a right-angled triangle low above the eastern horizon as the dawn gets underway.

Friday

27 As they rise above the east-northeast horizon, mag. –3.9 Venus appears 1.1° from the centre of the 10%-lit waning crescent Moon. Given a flat horizon, both objects will be visible from the centre of the UK at 04:00 BST (03:00 UT).

Sunday ▶

29 Mag. –2.1 Jupiter and mag. +0.7 Mars appear 0.6° apart in this morning's sky. Catch them rising in the east around 03:00 BST (02:00 UT).



NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

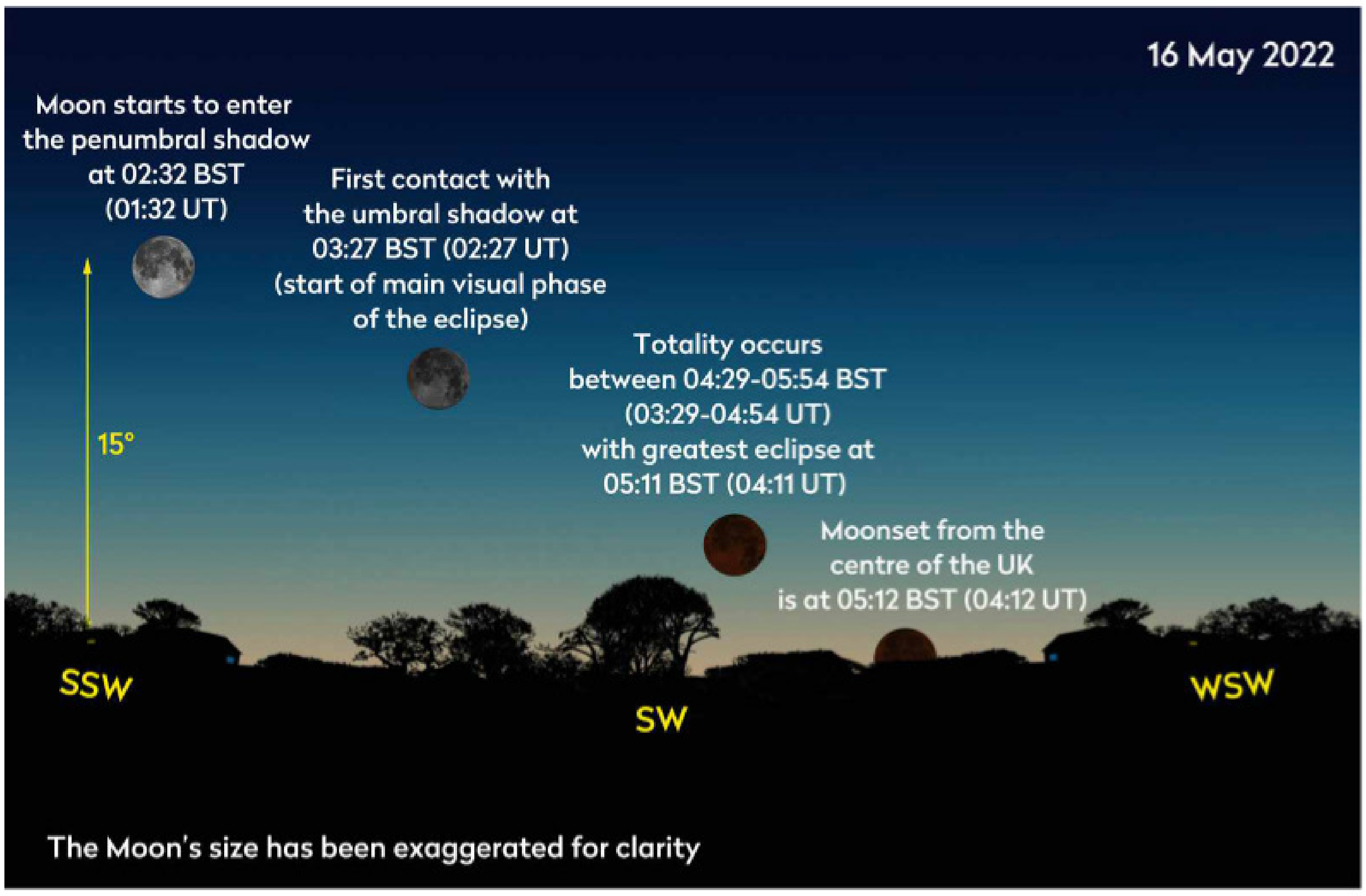
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

Total eclipse of the Moon

BEST TIME TO SEE: The morning of 16 May, from 02:32 BST (01:32 UT) until moonset



▲ The eclipse begins as the Moon enters Earth's penumbral shadow at 02:32 BST (01:32 UT)

A total eclipse of the Moon occurs on 16 May. The Moon's 5° orbital tilt normally has it passing above or below Earth's shadow in space. It's only when there's a straight-line alignment between the Sun, Earth and Moon that the Moon crosses into Earth's shadow. When this happens, the observers on Earth's hemisphere facing the Moon witness a lunar eclipse. This is what will happen on the morning of 16 May, when we in the UK will be in the right hemisphere for the first half of the eclipse.

At the Moon's distance, Earth's shadow has two parts: a weak outer penumbra and a dark umbra. The penumbral shadow is the region where, if you were on the Moon looking back towards the Sun, you would see it partially eclipsed by Earth. At the outer edge of this shadow the partial solar eclipse would be tiny, increasing in magnitude the deeper into the penumbra you go. The umbral shadow sits at the centre of the penumbra and is the part of Earth's shadow where all of the Sun's light would be blocked from view. The darkness of the penumbra increases towards the umbra.

Earth casts an interesting shadow because it has an atmosphere. Light skimming the edge of our planet is refracted to partly infill the umbra. As our atmosphere scatters blue light, light that has passed through it tends towards the redder end of the spectrum, giving the umbra a red or orange colour.

Things kick off with the penumbral eclipse at 02:32 BST (01:32 UT). This is a weak part of any lunar eclipse and difficult to detect. As the Moon moves deeper into the penumbra the shadow's depth increases, and you're likely to see this as a dark shading near the western limb. It becomes darker until the Moon encounters the umbral shadow at 03:27 BST (02:27 UT). The umbral shadow is distinct and darker than the penumbra. The ensuing partial phase of the eclipse grows in magnitude until, at 04:29 BST (03:29 UT), the Moon is engulfed in dark shadow: this is the start of totality.

All the while, dawn will be progressing to create an interesting conundrum. Whereas a bright non-eclipsed Moon is easy to see against bright sky, an eclipsed Moon against such a sky may seem to vanish from view, depending on the eclipse's darkness. From the UK, the Moon sets just after the point of greatest eclipse, timed for 05:11 BST (04:11 UT).

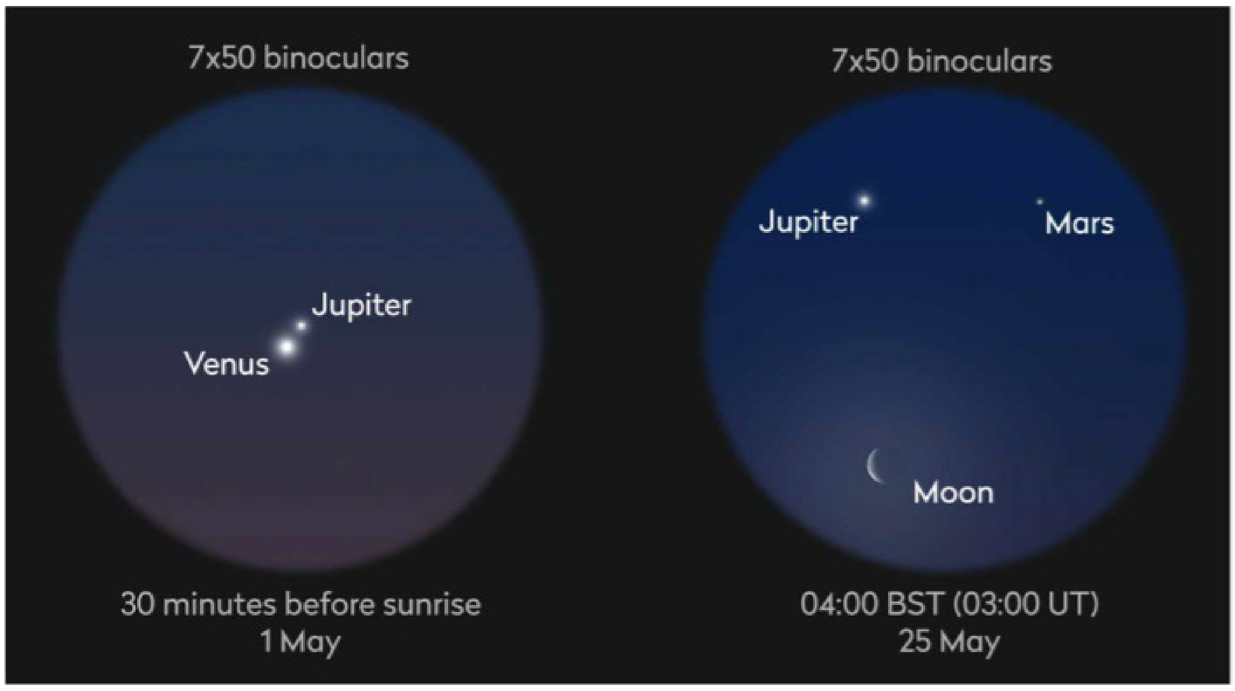
▲ Light passing through Earth's atmophere gives total lunar eclipses a reddish hue

ALL PICTURES: PETE LAWRENCE

May conjunctions

BEST TIME TO SEE: Mornings of 1–5 May, 18 May and 25–31 May

▼ Looking through 7x50 binoculars to catch conjunctions on 1 May and 25 May



There are several impressive conjunctions occurring this month. On 1 May, the bright planets Venus and Jupiter appear close in the morning sky. The position for this conjunction isn't ideal as the pair remain low as dawn breaks. However, with a clear eastern horizon it should be possible to see them both. Their visibility is assisted by their brightness, Jupiter at mag. –2.0 and Venus at mag. –4.0. At 05:00 BST (04:00 UT) they appear 22 arcminutes apart, less than the apparent diameter of the full Moon. On subsequent mornings, both planets will appear to separate, with Jupiter appearing west of Venus. By 5 May, their apparent separation will have increased to 4°, which is the equivalent of eight apparent diameters of the full Moon.

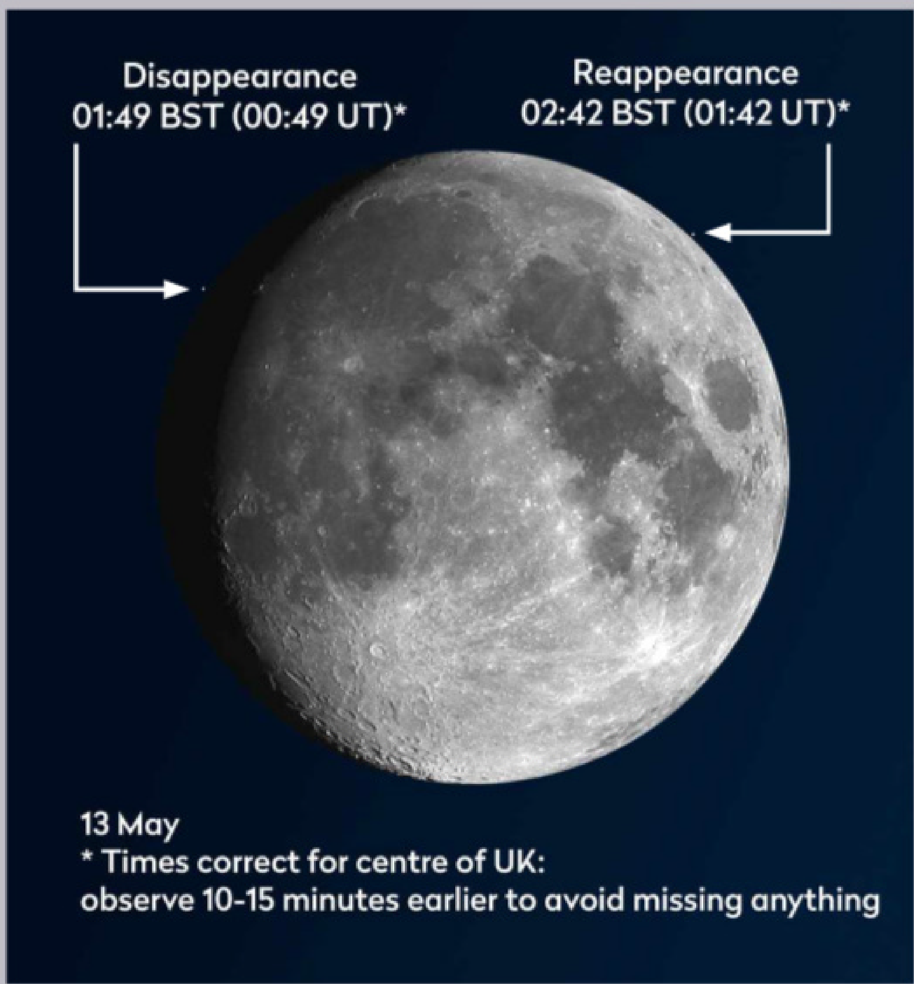
All the while, Mars will be heading in from the west. Before it meets up with Jupiter later in the month, Mars passes half a degree to the south of mag. +7.9 Neptune on the morning of 18 May. This meeting takes place under twilight conditions and in honesty, with low altitude it's unlikely to be that easy to see. Perhaps this is an interesting exercise for a camera to try and record.

Having brightened to mag. +0.7, Mars meets mag. –2.1 Jupiter on the mornings of 25–31 May. Again, the dawn twilight will be brightening as the pair gain altitude, but their relative brightness should allow both planets to be seen fairly easily with the naked eye. In order to spot them, find a location with a flat, clear eastern horizon. They rise around 03:00 BST (02:00 UT). On the morning of 25 May, a 25%-lit waning crescent Moon sits to the south of Mars, adding an extra element to this show.

Lunar occultation of Porrima

▼ Watch for Porrima's disappearance and reappearance behind the Moon's disc on 13 May

BEST TIME TO SEE: 13 May from 01:30 BST (00:30 UT)

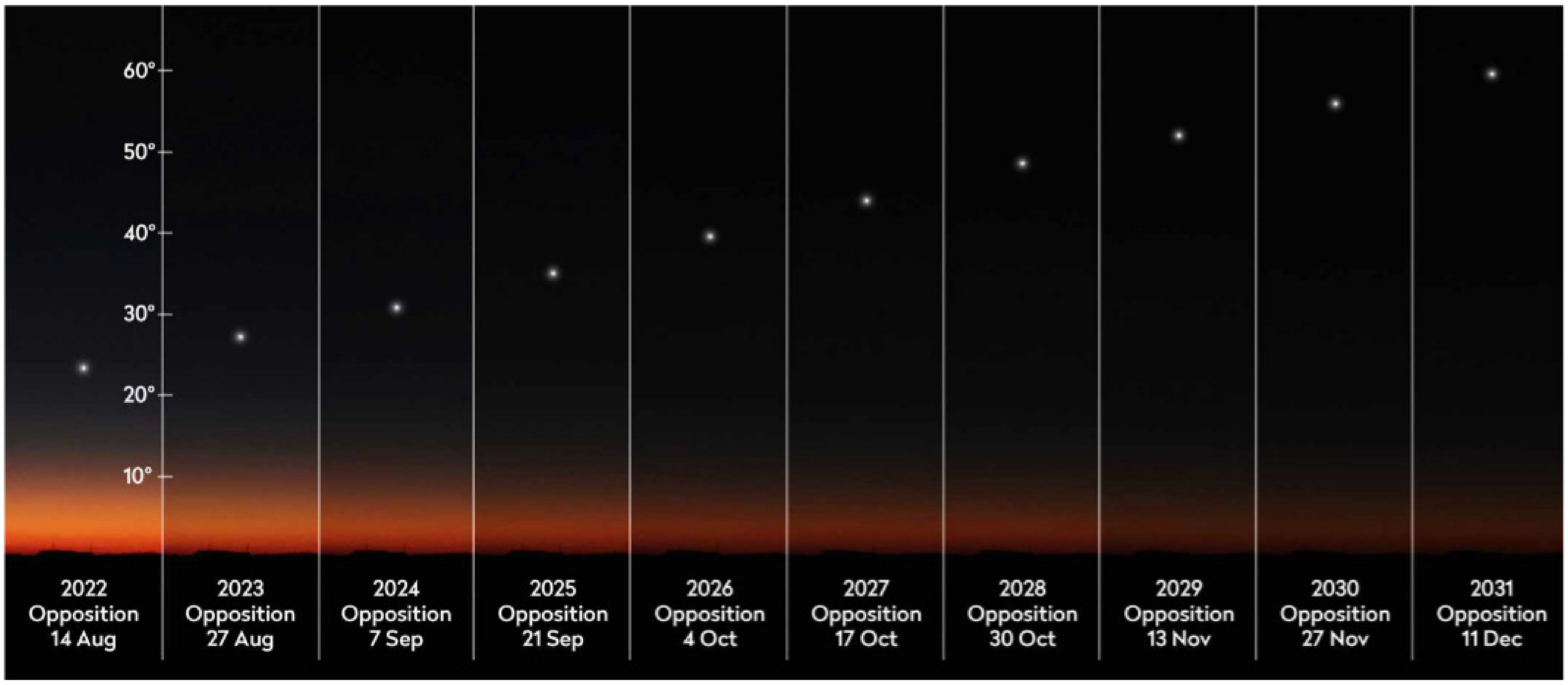


On the morning of 13 May, the 87%-lit waxing gibbous Moon will occult the binary star Porrima (Gamma (γ) Virginis). The event occurs at 01:50 BST (00:50 UT) as seen from the centre of the UK, Porrima disappearing behind the Moon's dark limb. This time may vary by up to a few minutes either side depending on your actual location. The best strategy is to observe from 01:30 BST (00:30 UT), first locating the Moon and then the star. This will ensure you don't miss anything.

The Moon's orbital motion keeps it moving east against the background stars. Eventually, it will have moved sufficiently far to allow Porrima to re-emerge from behind the Moon's bright edge. This will occur at 02:42 BST (01:42 UT) as seen from the centre of the UK, and again, it's wise to start observing 10-15 minutes earlier than this time to make sure you don't miss it.

Porrima is a binary star with an orbital period of 169 years. Back in the early 2000s the apparent separation of the two components was so small that it was virtually impossible to split them. Now that situation has improved somewhat and the two similarly bright stars (mag. +3.6 and mag. +3.7), appear separated by a little over 4 arcseconds.

THE PLANETS Our celestial neighbourhood in May



▲ **Saturn only reaches a low altitude as seen from the UK this year, but over the next decade it will climb higher**

PICK OF THE MONTH

Saturn

Best time to see: 31 May, 03:00 UT
Altitude: 16° (low)
Location: Capricornus
Direction: Southeast
Features: Rings, subtle banding on the planet, moons
Recommended equipment: 75mm, or larger

PETE LAWRENCE X 2

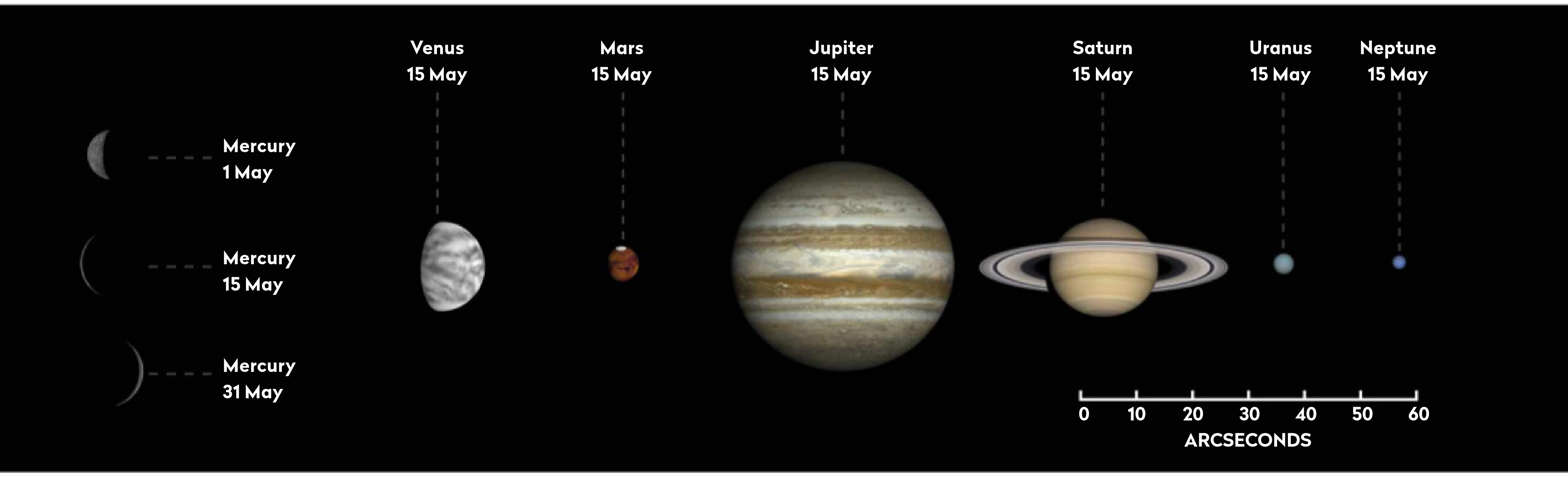
Saturn is a morning planet this month with a low altitude before sunrise. Shining at mag. +0.9 at the month's start, it brightens marginally by May's close to reach mag. +0.8. On the morning of 22 May a 57%-lit waning gibbous Moon sits 5.8° south of Saturn. By the month's end, Saturn only attains an altitude of 14° before the morning dawn twilight begins to reduce its visibility, but it should be possible to follow it through to an altitude of around 16°.

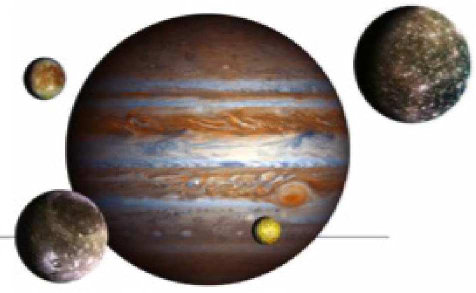
Saturn doesn't handle poor seeing well. The view of the delicate rings, which encircle the planet's globe, is smeared and smudged if the atmosphere is unstable. A good test for how stable the view is comes in the form of the dark Cassini Division, an apparent gap between the outer A ring and the B ring. Under good seeing the Cassini Division stands out well, and it's possible to follow it most of the way around the Earth-facing section of the rings. This is easier when they are at maximum tilt towards Earth, which they aren't at present. In the middle of May, Saturn's tilt approaches a minimum for the year at around 12.2°, the north pole being the one tilted towards Earth.

Although views of Saturn from the UK have have suffered from low altitude in recent years the planet will get higher, reaching a peak altitude around 21° from central UK under dark skies later this year.

The planets in May

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 1 May, 30 minutes after sunset
Altitude: 12°
Location: Taurus
Direction: West-northwest

Following last month's evening appearance, Mercury remains well placed at the start of May. Shining at mag. +0.7 on the evening of 1 May, it lies 1.9° from the Pleiades and sets over 2 hours after the Sun. By the end of May's first week, Mercury will appear at mag. +1.8, still lingering an impressive 2 hours after sunset before setting.

The planet then dims, reaching mag. +4.0 on 15 May and setting 55 minutes after sunset. It'll be lost from view earlier than this, about 10 May. Inferior conjunction occurs on the 21st and it returns as a poorly positioned morning object after this date.

Venus

Best time to see: 31 May, 30 minutes before sunrise
Altitude: 6° (low)
Location: Pisces
Direction: East

Venus shines at mag. –4.0 at May's start, visible in the morning sky, rising 1 hour before the Sun. At this time, Venus will appear close to the dimmer but still bright Jupiter. Shining at mag. –2.0, Jupiter will lie 22 arcminutes from Venus on 1 May, visible above a flat eastern horizon from around 50 minutes before local sunrise. The planets separate after 1 May as Venus drifts to the east. On the morning of the 27th, look out for a 10%-lit waning crescent Moon, 1.1° southeast of Venus. Again, a flat eastern horizon will be needed to spot this pairing.

Mars

Best time to see: 31 May, 03:00 UT
Altitude: 10° (low)
Location: Pisces
Direction: East

Mars is currently in the morning sky. On 1 May, it shines at mag. +0.9 and rises 90 minutes before the Sun. By the time the end of the month arrives, it will have brightened to mag. +0.7 and rises two hours before the Sun. It has a close encounter with mag. –2.1 Jupiter on 28, 29 and 30 May, the planets appearing 37 arcminutes apart on the 29th. A few mornings earlier, on 25 May, look out for a low arrangement of Mars, Jupiter and a 25%-lit waning crescent Moon. By 31 May, through a telescope, Mars will have grown in size to about 6 arcseconds across and shows an 87%-lit gibbous phase.

Jupiter

Best time to see: 31 May, 03:00 UT
Altitude: 10° (low)
Location: Pisces
Direction: East

Jupiter is a morning planet, lying 22 arcminutes from mag. –4.0 Venus on 1 May. It will be mag. –2.0 on this date and will be an impressive sight from a flat eastern horizon. View from 40 minutes before sunrise.

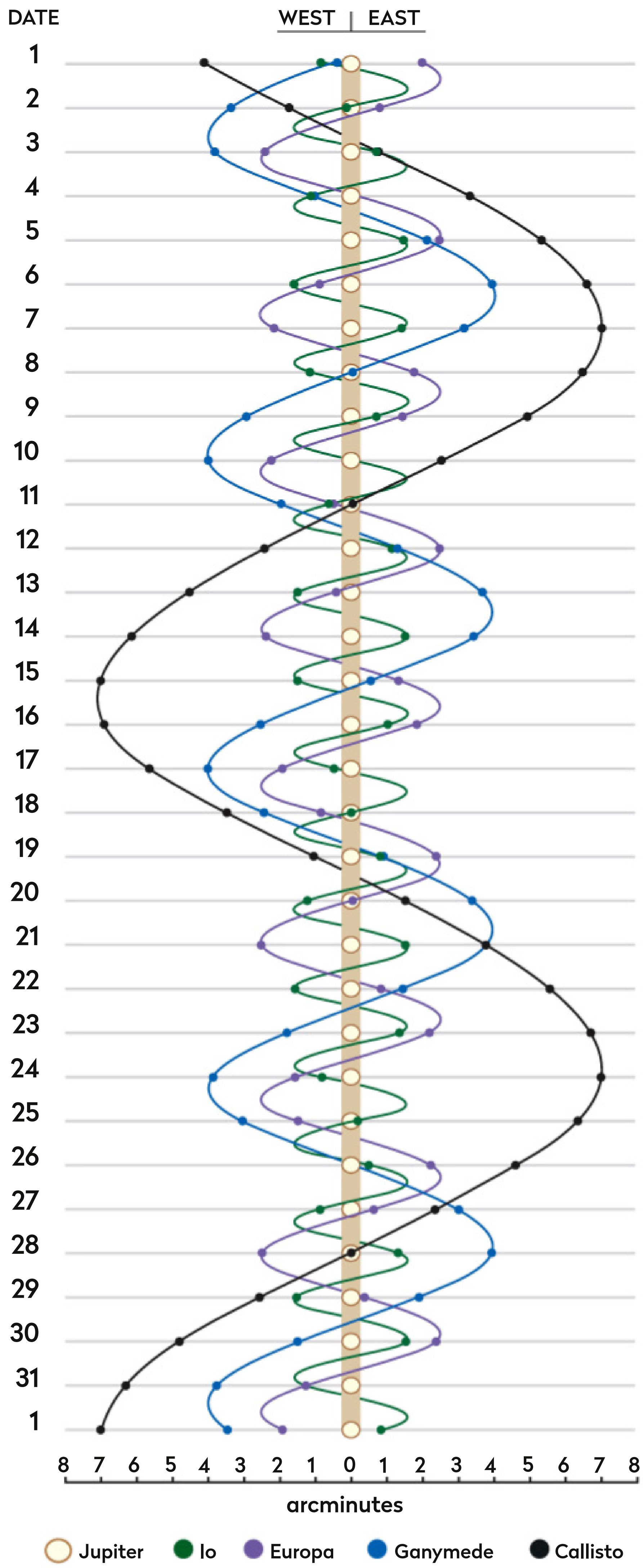
Venus departs the scene over the following mornings, but Jupiter isn't left alone, being joined by Mars towards the month's end. On the 25th, mag. –2.1 Jupiter, mag. +0.7 Mars and a 25%-lit waning crescent Moon may be seen low above the eastern horizon from around 1 hour before sunrise. Jupiter appears closest to Mars on 29 May, the pair separated by 37 arcminutes.

Not visible this month

Uranus, Neptune

JUPITER'S MOONS: MAY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT.)



THE NIGHT SKY – MAY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

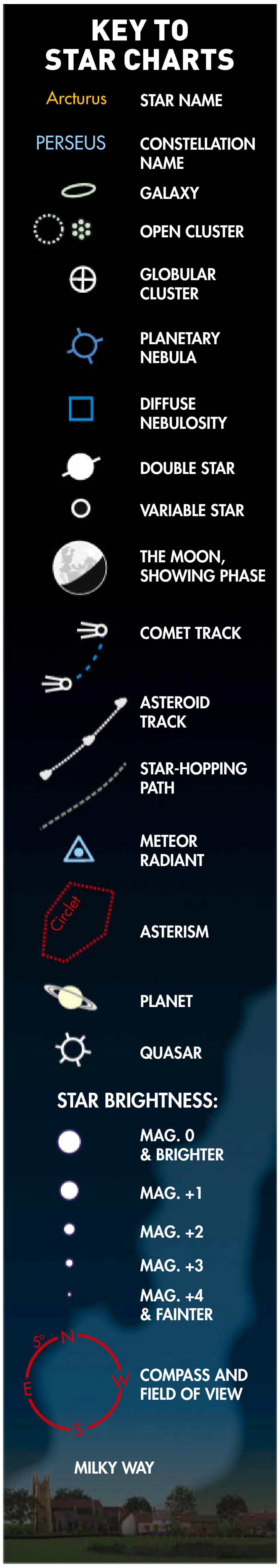


CHART: PETE LAWRENCE

When to use this chart

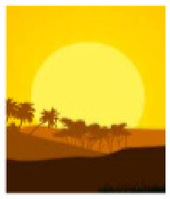
1 May at 01:00 BST
15 May at 00:00 BST
31 May at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in May*



Date	Sunrise	Sunset
1 May 2022	05:36 BST	20:40 BST
11 May 2022	05:17 BST	20:57 BST
21 May 2022	05:01 BST	21:13 BST
31 May 2022	04:49 BST	21:27 BST

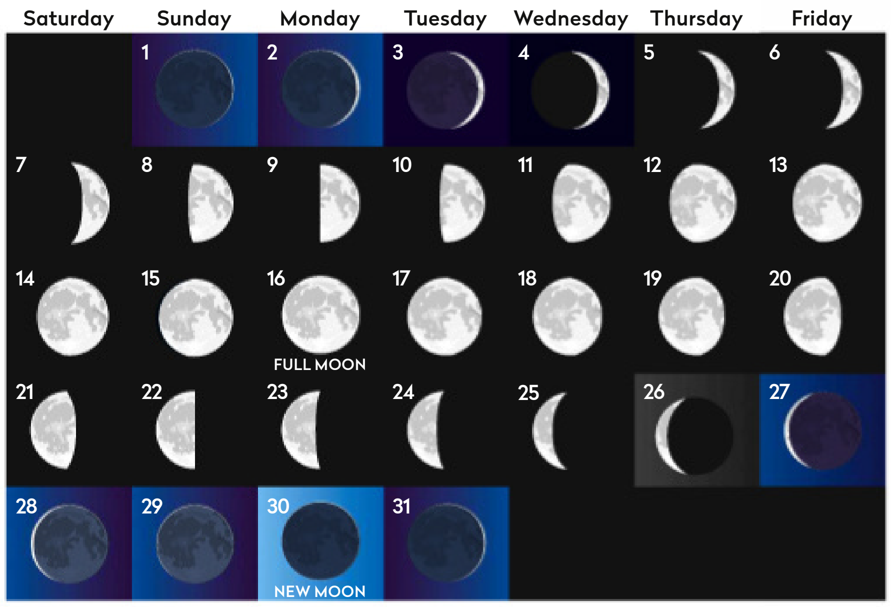
Moonrise in May*

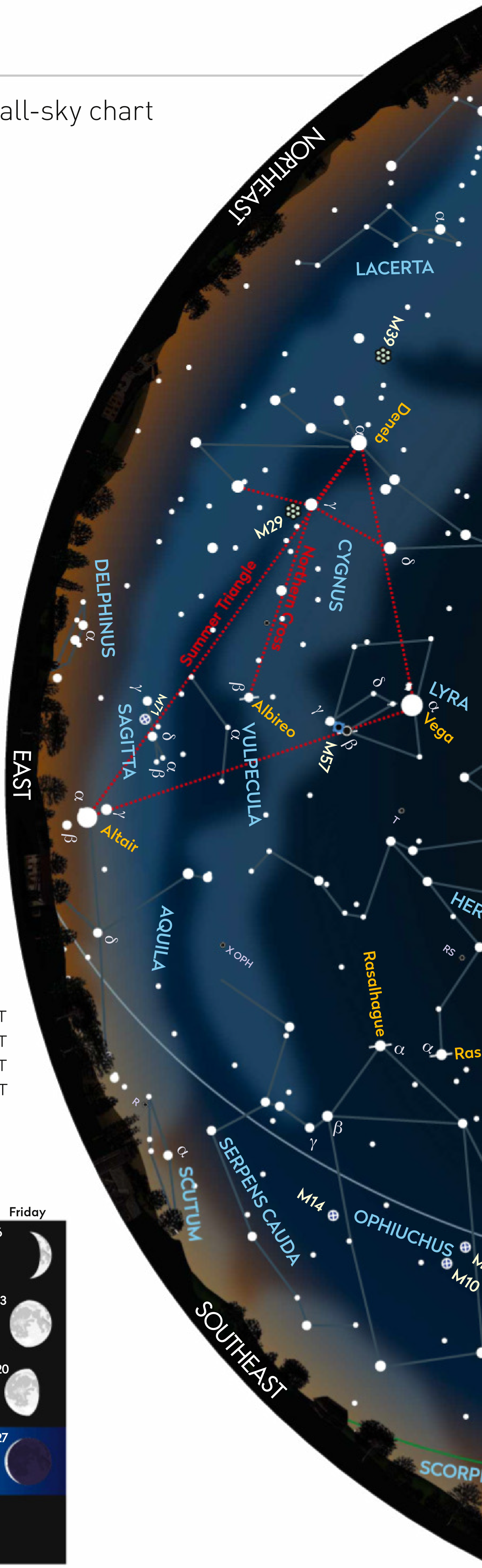
Moonrise times

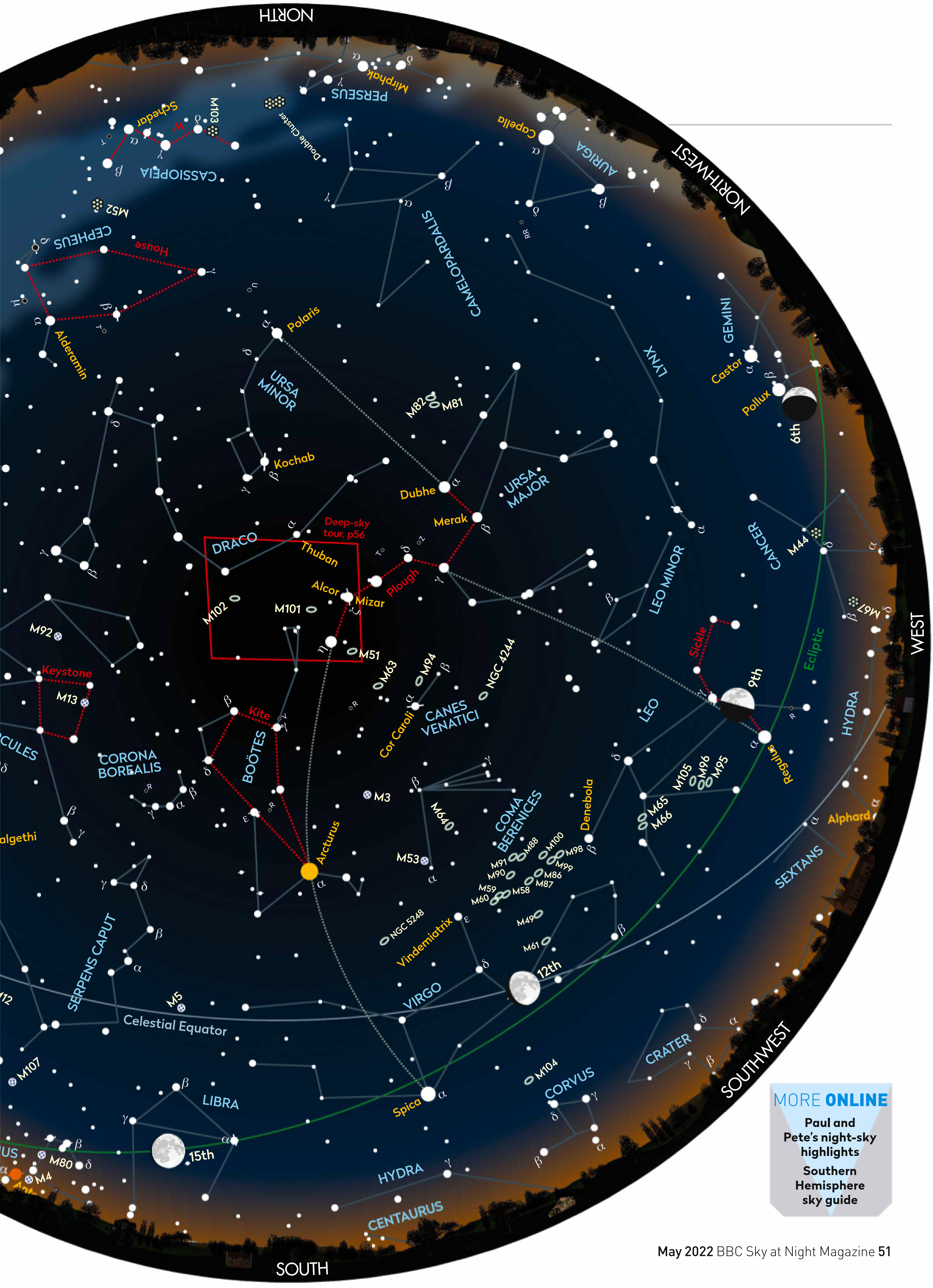
1 May 2022, 05:56 BST
5 May 2022, 07:43 BST
9 May 2022, 12:07 BST
13 May 2022, 17:28 BST
17 May 2022, 23:34 BST
21 May 2022, 02:24 BST
25 May 2022, 03:31 BST
29 May 2022, 04:19 BST

*Times correct for the centre of the UK

Lunar phases in May





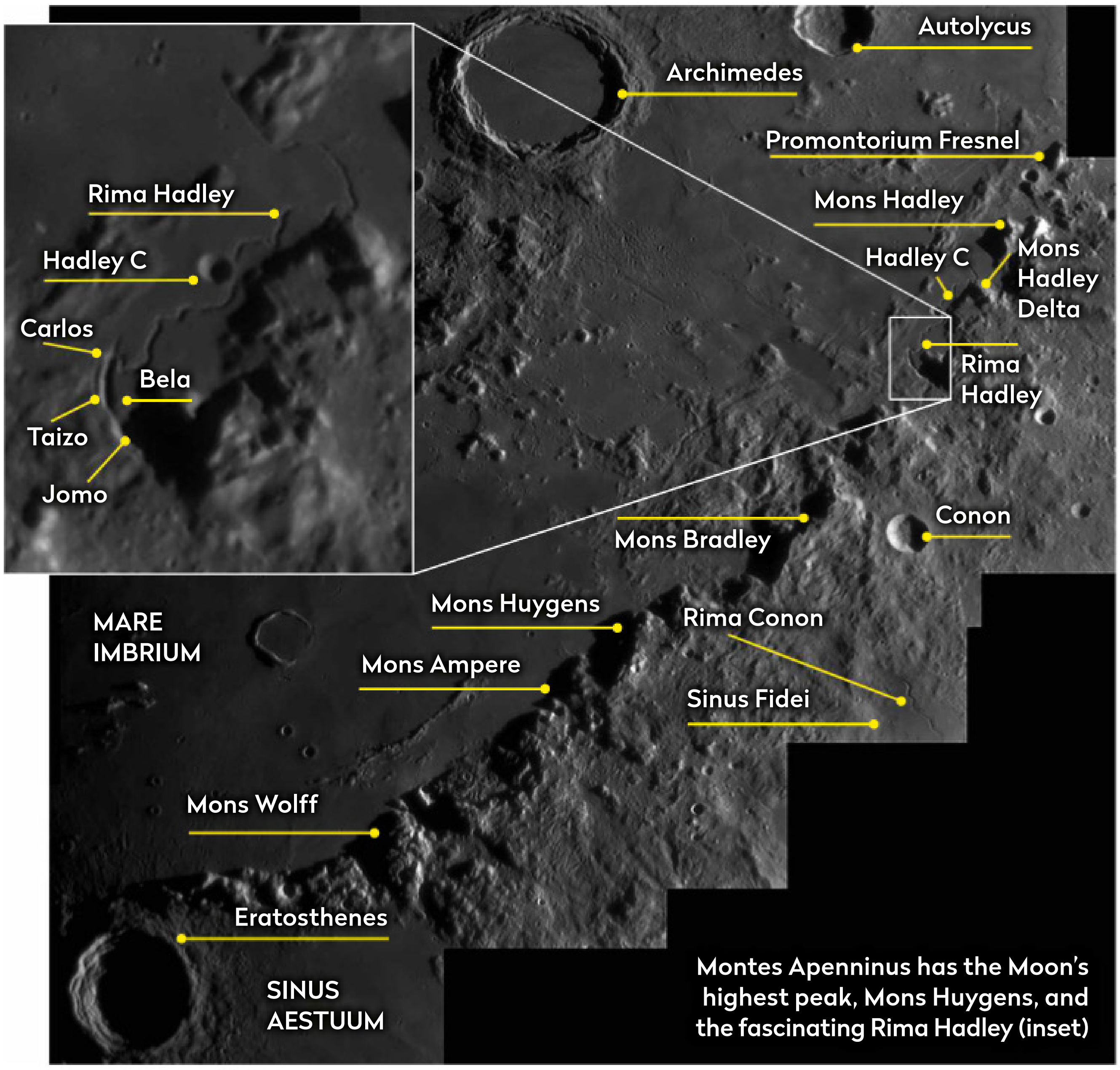


MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

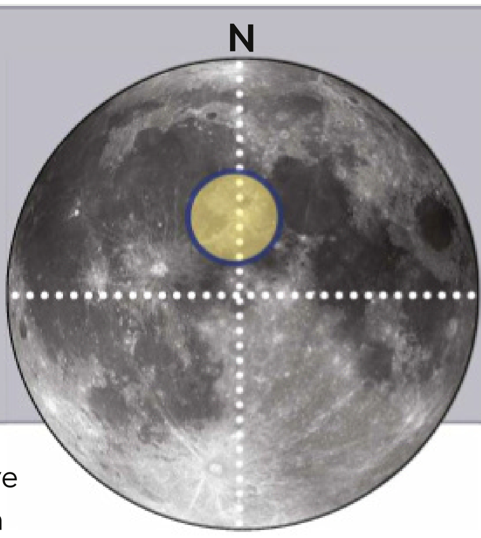
MOONWATCH May's top lunar feature to observe



Montes Apenninus has the Moon's highest peak, Mons Huygens, and the fascinating Rima Hadley (inset)

Montes Apenninus

Type: Mountain range
Size: 950km long, 100km wide
Longitude/Latitude: 0°, 19.9° N
Age: 3.2–3.9 billion years
Best time to see: First quarter (8–9 May) or six days after full Moon (22–23 May)
Minimum equipment: 10x binoculars



Montes Apenninus is the most impressive of the lunar mountain ranges visible from Earth. It borders 1,250km diameter **Mare Imbrium**, arcing from the eastern side of the Mare around to the south-southeast. It contains many lofty peaks, which cast striking shadows across Imbrium's relatively flat lava during the late waxing crescent and early waxing gibbous phases. With a low Sun angle, the jagged peak shadows give a highly exaggerated impression of the mountains within the Apenninus range.

The northern edge of the range begins with **Promontorium Fresnel**, a rugged outcrop on the southern edge of a lava corridor between 650km Mare Serenitatis to the east and Mare Imbrium. The Apennine mountains appear steep to the western side of the range facing Mare Imbrium; the eastern flanks fall away more gently as they extend radially from the centre of the Imbrium Basin.

The northern part of the range contains **Mons Hadley**, a mountain that rises to a height of 4,500m. To its south is the **Mons Hadley Delta**, another tall peak rising to 3,500m, which was seen and photographed as a backdrop during the Apollo 15 mission. A lava inlet to the west and southwest of Mons Hadley Delta is home to the most famous sinuous rille (winding groove) on the Moon, **Rima Hadley**. Snaking northeast and southwest of 6km **Hadley C**, the rille requires at least 200mm of aperture to see and is a joy to image using high resolution imaging equipment. The rille's southern end is marked by four small craters; 5km **Carlos**, 8km **Taizo**, 12km x 2km **Bela** and 7km **Jomo**.

Progressing south takes us over more high-elevation, sheer cliff faces bordering Mare Imbrium. The largest crater to interrupt the range's southeast flank is 22km **Conon**. It sits near 4,200m-high **Mons Bradley**.

Those with 300mm or larger instruments, or high-resolution imaging setups may like to try for **Rima Conon**, which sits 82km to the south of Conon in **Sinus Fidei**, the Bay of Trust. It is 45km in length, but only 2km wide.

There are more sheer cliffs at Mare Imbrium's edge as the range continues to arc towards the southwest. Two standout peaks appear here in the form of **Mons Huygens** and **Mons Ampere**. Mons Huygens is the tallest mountain on the Moon with a height of 5,500m. As the Apennines arc toward a more westerly direction along the south-southeast edge of Mare Imbrium, the massive triangular form of 3,500m-high **Mons Wolff** can be seen. After Mons Wolff, the width of the range narrows considerably, the southern Apennine slopes being replaced by the lava of **Sinus Aestuum**, the Seething Bay, a large, flat 230km-diameter expanse of lava to the south.

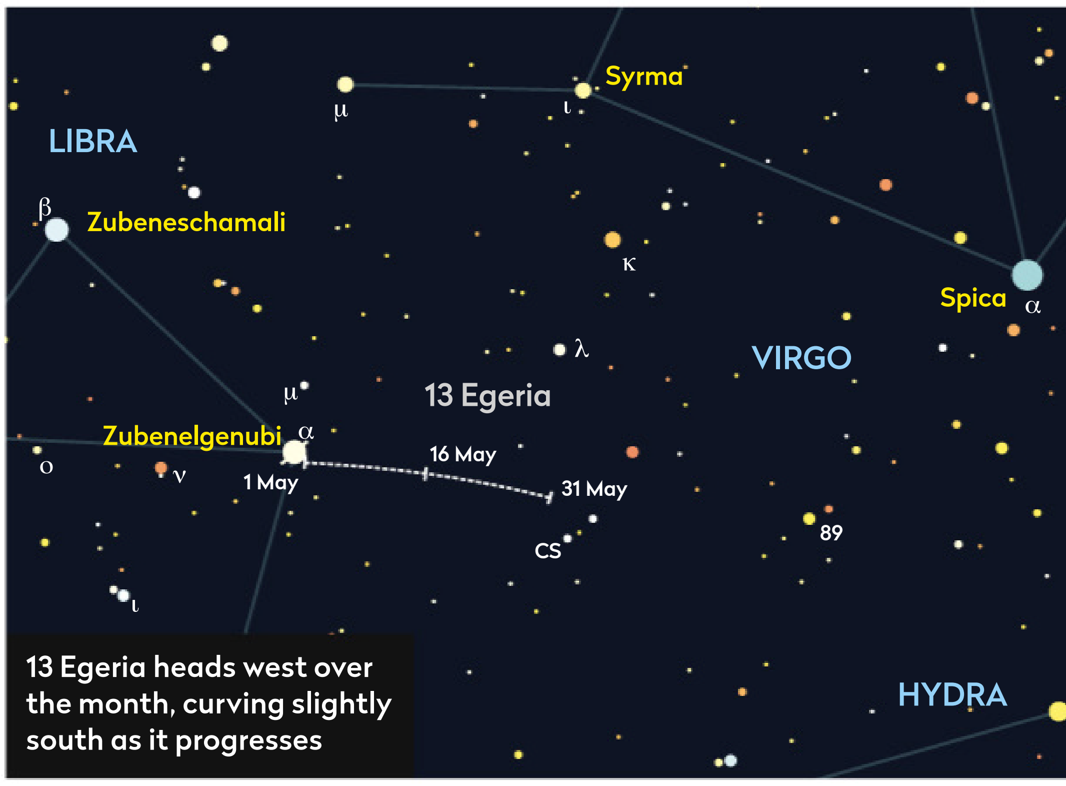
Montes Apenninus contains many peaks, which cast striking shadows

Montes Apenninus ends near 60km **Eratosthenes**, a beautiful example of a circular terraced crater with a central mountain complex. Eratosthenes is younger than Montes Apenninus and its ejecta ramparts, outside the main rim, can clearly be seen overlapping the last peaks of the Apenninus mountains to the north.

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

13 Egeria reaches opposition in the constellation of Libra, the Scales



13 Egeria heads west over the month, curving slightly south as it progresses

Minor planet 13 Egeria reaches opposition on 4 May when it can be found shining at 10th magnitude in Libra, the Scales, less than a degree to the west-southwest of mag. +2.7 Zubenelgenubi (Alpha^2 (α^2) Librae). Zubenelgenubi is the name given to the brighter, eastern component of a double star. The fainter companion, Alpha^1 (α^1) Librae, shines at mag. +5.2 and is located 3.8 arcminutes to the northwest of Alpha^2.

At 01:00 BST (00:00 UT) on 1 May, 13 Egeria is located about 20 arcminutes southwest of Zubenelgenubi, shining at mag. +10.1. It reaches its peak opposition brightness of mag. +10.0 on 4 May, remaining that bright for a couple of days before dimming again. By the month's close, 13 Egeria will have faded to mag. +10.8. Its monthly track has it heading west, curving and tilted slightly south. It crosses the border from Libra into Virgo on 28 May.

Egeria was discovered by Annibale de Gasparis on 2 November 1850. It is a main belt asteroid, taking 4.14 years to complete its orbit around the Sun. Its orbital distance varies from 2.79 AU at perihelion to 2.36 AU at aphelion, and it spins on its axis once every 7.05 hours. Egeria was named after a mythological nymph and is a dark object with an albedo of just 8.25 per cent, a figure which indicates how much light is reflected by its surface. It's an uncommon type of carbonaceous asteroid known as a G-type, which accounts for just 5 per cent of the asteroid population.

Its occultations of stars have given us details about the asteroid's physical size. One such event on 8 January 1992 gave us dimensions of 217km x 196km. A second opportunity, on 22 January 2008, meant its size could be refined to 214.8km x 192km.

STAR OF THE MONTH

Izar, a stunning double star situated in Boötes

Izar (Epsilon (ε) Boötis) is the next star 'up' the eastern side of the Kite asterism, which begins in the south with the bright spring star Arcturus (Alpha (α) Boötis).

The Kite forms the main body of Boötes, the Herdsman. Izar is a beautiful double star consisting of a mag. +2.4 K0 II-III orange primary, separated from a mag. +5.1 A2 V white secondary by 2.8 arcseconds. The difference in colours between both stars is what makes the pair so striking through the eyepiece, something which was noted by their discoverer FGW Struve, who named them Pulcherrima, meaning 'loveliest' in Latin.

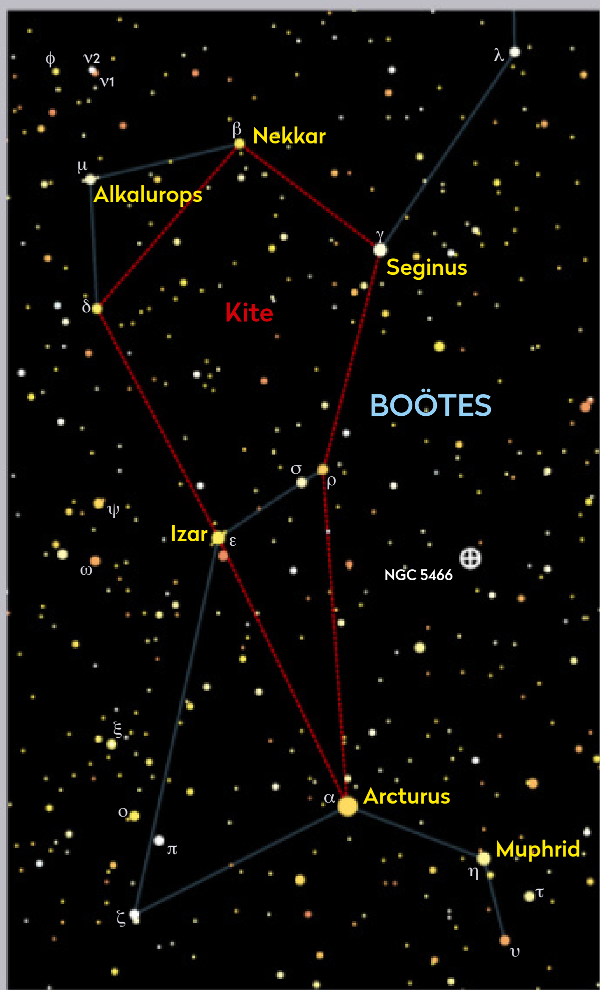
The Izar system lies 203 lightyears away. At that distance, the apparent separation indicates that the two stars are 185 AU apart. They are believed to be in an orbit that takes 1,000 years to complete.

The primary is a late-stage star which has exhausted its supply of core hydrogen. It has a mass 4.6 times greater than our Sun, but its evolutionary state means it has swelled to be 33 times larger. Its secondary companion is more like our Sun: still on the main sequence of stellar evolution and estimated to be 2.2 times more massive and 2.7 times larger. But where our Sun rotates at the leisurely speed of 2km/s, Izar B rotates at 123km/s.

Eventually, like our Sun, Izar B will exhaust its core hydrogen and swell into a red giant. By the time this has occurred, the primary will have shed its outer layers to form a planetary nebula, and the core will have become a white dwarf.

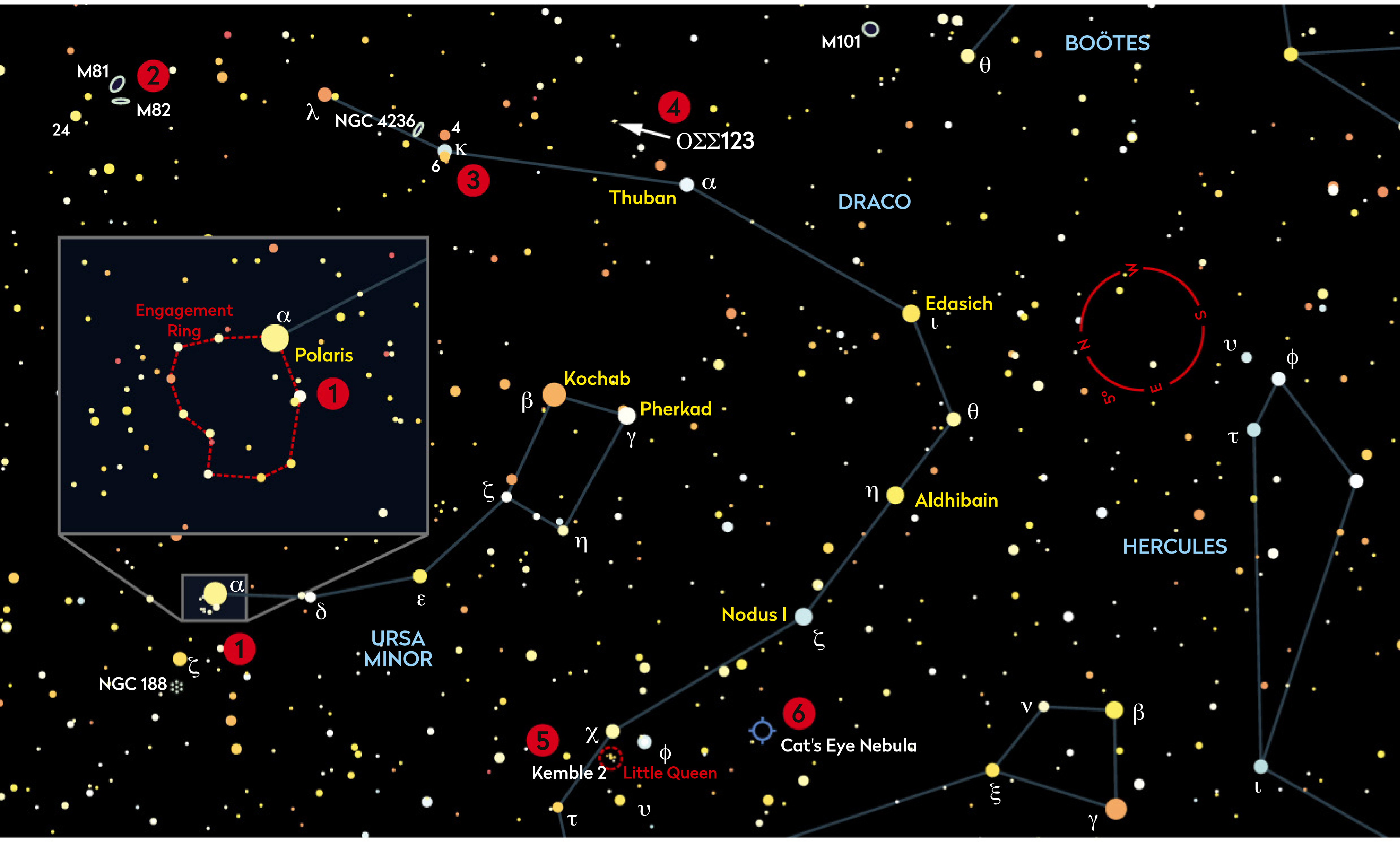
The name Izar is from an Arabic phrase for 'girdle' or 'loin cloth', a meaning that is also attributed to the similar-sounding Mizar (Zeta (ζ) Ursae Majoris). It is highest in the sky, due south at 01:00 BST (00:00 UT) on 1 May, 00:00 BST (23:00 UT) on the 15th and 23:00 BST (22:00 UT) on the 31st.

▼ Izar, a beautiful double star in the Kite Asterism, is located 203 lightyears away



BINOCULAR TOUR With Steve Tonkin

This month we travel from the North Celestial Pole to the North Ecliptic Pole



1. Polaris 'Engagement Ring'

10x 50 Most astronomers use mag. +2.0 Polaris (Alpha (α) Ursae Minoris) as a mere marker for the North Celestial Pole (NCP), but binoculars reveal that it is part of an asterism, a circlet of mostly 8th and 9th magnitude stars: like a diamond in an engagement ring. Notice that one of the stars in the circlet is slightly displaced away from Polaris; this star is on the line joining Polaris and the NCP, and enables the NCP to be more precisely located.
☐ **SEEN IT**

2. Galaxy pair M81 and M82

15x 70 The next stop in this month's tour of the north polar region of the sky takes us to the galaxy pair M81 (Bode's Galaxy) and M82 (The Cigar Galaxy). Use the chart to help you identify mag. +4.6 24 Ursae Majoris and you should be able to get the galaxies in the same field of view. M81 is the brighter and easier of the pair; fainter M82 may need averted vision. ☐ **SEEN IT**

3. Kappa Dra group

10x 50 Our next target is an attractive little line of coloured stars. The brightest of these is the hot (13,727˚C) blue-white mag. +3.9 Kappa (κ) Draconis, which shines brighter than 500 Suns. To the north are two orange stars, the brighter of which is mag. +4.9 6 Draconis. At the other end of this line of four, the most southerly star is ruddy 4 Draconis, a long-period pulsating variable (mag. +4.9 to +5.0). ☐ **SEEN IT**

4. ΟΣΣ123

10x 50 ΟΣΣ123 is at the end of a 4°-long chain of stars that extends west from mag. +3.7 Thuban (Alpha (α) Draconis). With magnitudes of +6.6 and +7.0, and a separation of 69 arcseconds, the components of this double star are easy to split. The 'ΟΣΣ' designates Otto Wilhelm von Struve's catalogue of double stars. Otto Wilhelm was one of 18 children of the 19th-century astronomer Friedrich Georg Wilhelm von Struve. ☐ **SEEN IT**

5. Kemble 2

10x 50 In the same field of view as mag. +3.6 Chi (χ) Draconis, only 1° to the east, is a little equilateral triangle of 7th magnitude stars. You will see a pair of fainter stars that complete a trapezium, of which the triangle is a part; it forms a 'W' with the fainter stars at the tips. This similarity to the 'W' of Cassiopeia gives the group its name, 'Little Queen'. ☐ **SEEN IT**

6. Cat's Eye Nebula

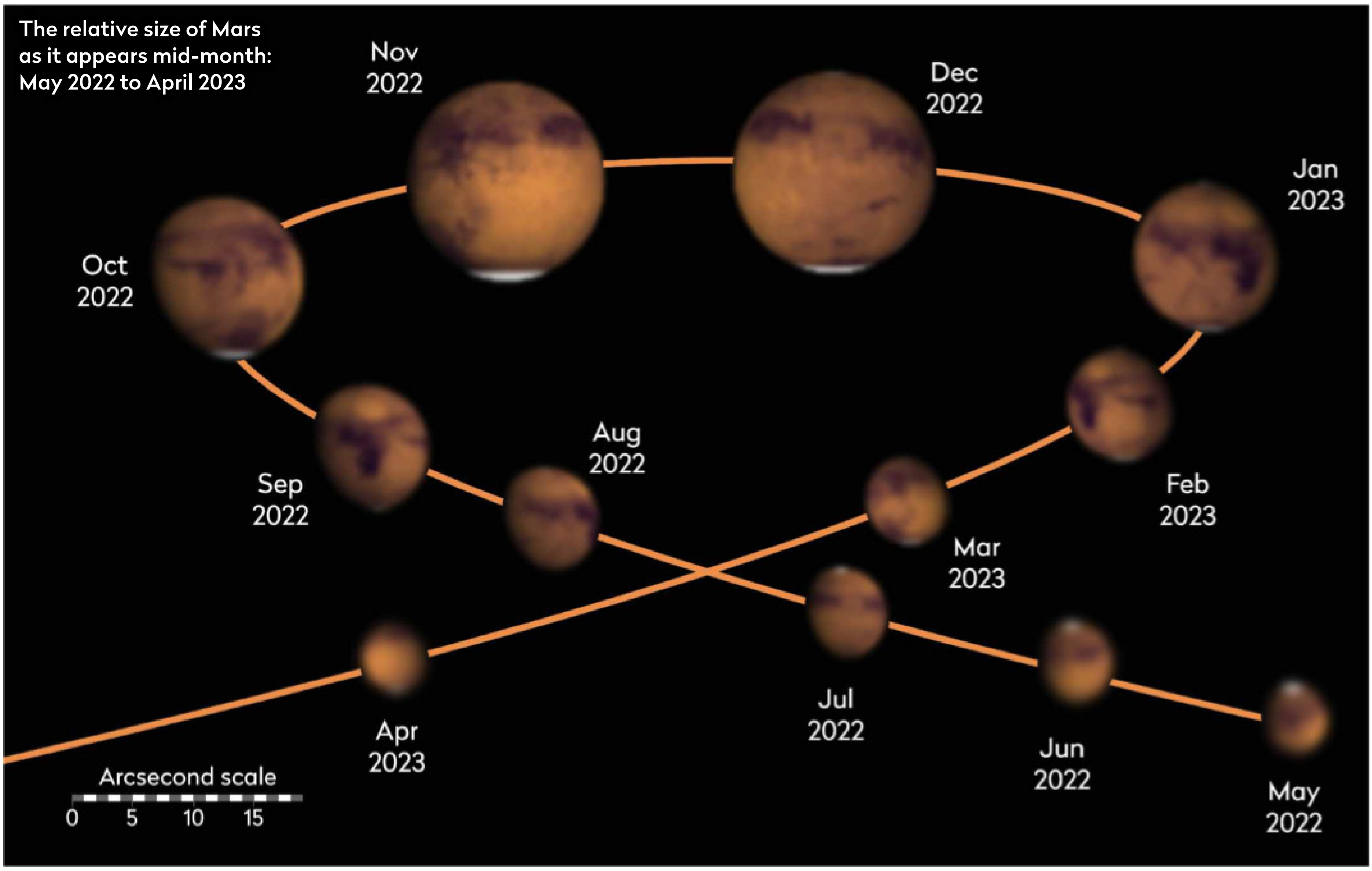
15x 70 We end with the Cat's Eye Nebula, which marks the position of the North Ecliptic Pole, a point on the northern celestial hemisphere that is always the same angular distance from the Sun, which is the centre of the circle that the NCP makes in its 25,770-year precessionary cycle. It looks like an ethereal green star and winks at you if you change from averted to direct vision. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you record the size of Mars's disc, in the run up to opposition and beyond?



Mars reaches an apparent diameter of 6 arcseconds on 31 May, pretty small but a viable size to record the planet as a disc. This month's challenge is intended to extend right through into 2023 as we want to you start imaging or drawing the planet at regular intervals from now until opposition on 8 December this year, and then through into the following year.

The start of this long-term project won't be too easy because Mars will be located in the brightening morning twilight, with it being best placed at the end of the month. The frequency of recording will need to be adjusted with the weather, but an observation a week or two apart at the start of the sequence should be sufficient.

The planet will remain tricky through June and most of July, but then the lengthening nights and a brightening planet will work in your favour as we pass the summer solstice on 21 June. It takes tenacity to remain with a planet like this, especially as the earlier results will probably look quite poor. However, sticking to your guns and grabbing results when the weather allows is a great way to connect to a distant world like Mars.

Sticking to your guns and grabbing results when the weather allows is a great way to connect to a world like Mars

The 2022 opposition, on 8 December, will present Mars with a maximum apparent size of 17.2 arcseconds at the start of that month, which is someway short of last opposition's 22.6 arcseconds, achieved in October 2020. However, for the UK at least, Mars reaches opposition at a higher altitude this year and this will make a big difference. If you do manage to stick with Mars all the way from now through to – and possibly past – opposition, comparing results will give you a unique insight into how this planet can change in appearance dramatically.

If you aim to image Mars, you need to make a choice of whether you want to capture it in colour, monochrome, or monochrome with filters, to generate a colour result. If you are intending to do a colour capture, consider investing in an atmospheric dispersion corrector, or ADC, to reduce atmospherically induced colour fringing at the start of the project, which is a side-effect of low altitude.

An infrared-sensitive monochrome camera fitted with an infrared pass filter will give you a colour fringe-free result and will go some way to overcoming the effects of atmospheric turbulence. This is because longer wavelengths tend to be less affected by atmospheric seeing.

The distance between Mars and Earth will reduce as we approach December and surface detail should start to become more apparent in the months ahead of this. Additionally, constant recording will reveal the effects of the Martian weather and seasonal changes in the planet's polar caps.

DEEP-SKY TOUR

We look for objects along the borders of the constellations Ursa Major, Draco and Boötes

1 NGC 5907

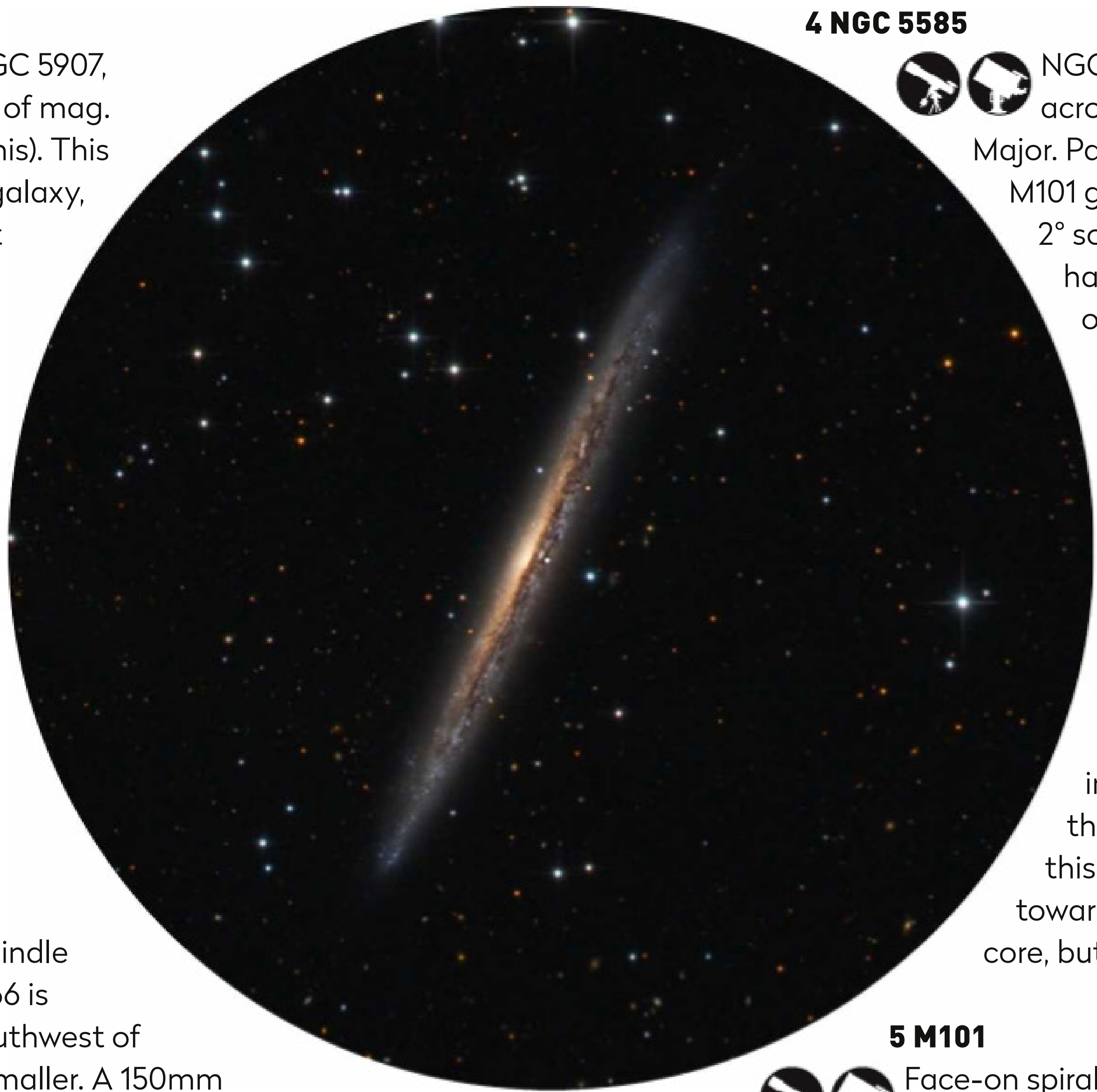
We start with NGC 5907, located 3° south of mag. +3.3 Edasich (Iota (ι) Draconis). This is a 10th magnitude spiral galaxy, presented edge-on. It's just about visible in a 150mm scope, appearing like a 6-arcminute glowing line. Larger apertures will increase the apparent size of the line and reveals the galaxy's true beauty. A 250mm scope reveals an object 9 arcminutes long and less than an arcminute wide with a brighter central section that represents the galaxy's core. ☐ **SEEN IT**

2 NGC 5866

Known as the Spindle Galaxy, NGC 5866 is located 1.4° to the west-southwest of NGC 5907, but it appears smaller. A 150mm scope reveals a bulging streak of light that is 2 arcminutes long, but again, less than an arcminute wide. Larger instruments don't 'grow' the apparent size that much: a 300m telescope reveals an apparent length of just 3 arcminutes. This is a sideways-on lenticular galaxy, made famous thanks to a Hubble shot that shows it to have a razor-thin dark dust lane running along its axis. This is difficult to see visually, but can be recorded using large astrophotography setups. ☐ **SEEN IT**

3 NGC 5678

Galaxy NGC 5678 is located just on the Draco side of the border with Ursa Major. The best 'manual' route for locating it is to drift 4.8° to the west of NGC 5866, where you'll come across the mag. +5.7 star HIP 71111. NGC 5678 is located 2.5° to the north of this star. The galaxy has an integrated magnitude of +12.1 and lies 2.6 arcminutes to the southeast of mag. +9.76 TYC 3866-0787-1. This star helps locate the object, but also provides a degree of natural 'light pollution' when looking for the fainter and more diffuse galaxy. A 300mm scope will reveal a 3x 1.5 arcminute object orientated north-south. ☐ **SEEN IT**



▲ **NGC 5907 is also know as the Knife Edge or Splinter Galaxy**

BERNHARD HUBL/CCDGUIDE.COM, CHART BY PETE LAWRENCE

4 NGC 5585

NGC 5585 requires a short hop across the border into Ursa Major. Part of what's known as the M101 group, NGC 5585 is located 2° southwest of NGC 5678. It has an integrated magnitude of +11.2 but as the galaxy is presented to us fairly face-on, it's little more than a faint glowing patch in a 150mm instrument, roughly an arcminute in diameter. A 250mm instrument fares little better, although the apparent size of the galaxy increases by a factor of three. The diffuse nature of this barred spiral brightens towards the galaxy's central core, but not by much. ☐ **SEEN IT**

5 M101

Face-on spiral galaxy M101 sits within the borders of Ursa Major. The classic way to locate M101 is to first identify the two stars at the end of the handle of the Plough asterism: Mizar (Zeta (ζ) Ursae Majoris) and Alkaid (Eta (η) Ursae Majoris). Imagine these as a base of an equilateral triangle and M101 sits where the triangle's vertex would lie, to the northeast. The galaxy's visual mag. +7.7 suggests an easier view than reality delivers, M101 appearing fainter due to it having a low surface brightness. A 150mm scope shows a 20x15 arcminute object, brightening towards its centre. Larger apertures will start to reveal structure in the core region and within the galaxy's arms. Also known as the Pinwheel Galaxy, M101, is 21 million lightyears away. ☐ **SEEN IT**

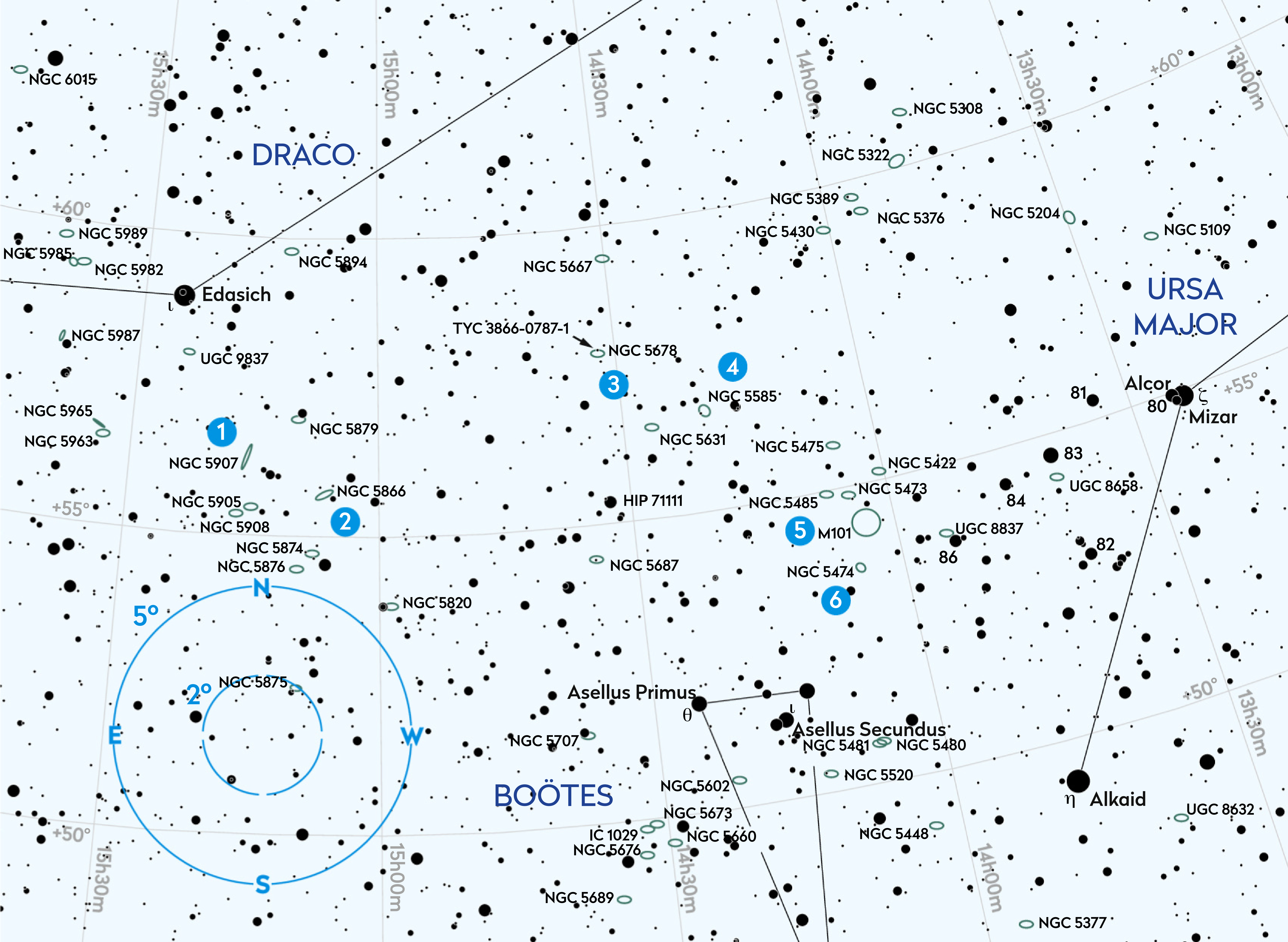
6 NGC 5474

Our final target sits close to the Draco–Ursa Major border. Lying just within the latter is NGC 5474, a mag. +11.3 dwarf galaxy, 0.7° south and a bit east of M101. The closest companion to M101, NGC 5474 is diffuse even in a large scope, appearing 3 arcminutes across. This galaxy is gravitationally influenced by M101 and distorted in such as way that its core is offset relative to the surrounding disc of stars and star-forming regions. As you would expect for a companion of M101, it shares a similar distance at 21.2 million lightyears. Amazingly there is evidence of spirality in NGC 5474's structure, although a large scope doesn't show much other than an asymmetric fuzzy patch. The spiral structures give rise to a rare object classified as a dwarf spiral. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.


DRACO
URSA MAJOR
BOÖTES
Edasich
Alcor
Mizar
Alkaid
Asellus Primus
Asellus Secundus
NGC 6015
NGC 5989
NGC 5985
NGC 5982
NGC 5987
UGC 9837
NGC 5894
NGC 5965
NGC 5963
NGC 5907
NGC 5879
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NGC 5908
NGC 5866
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NGC 5520
NGC 5448
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W
+60°
+55°
+50°
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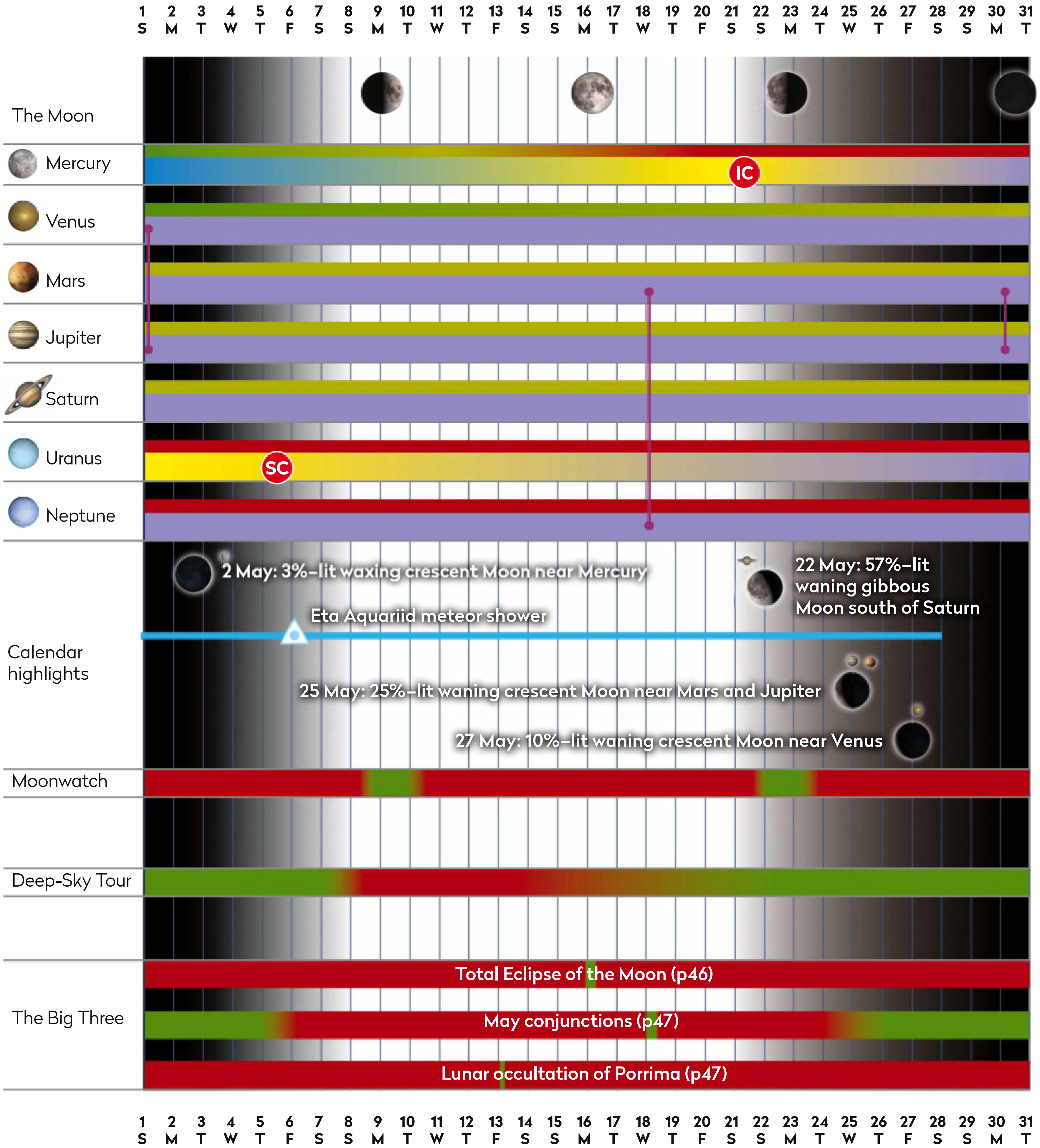
13h30m
14h00m
14h30m
15h00m
15h30m

AT A GLANCE

How the Sky Guide events will appear in May



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

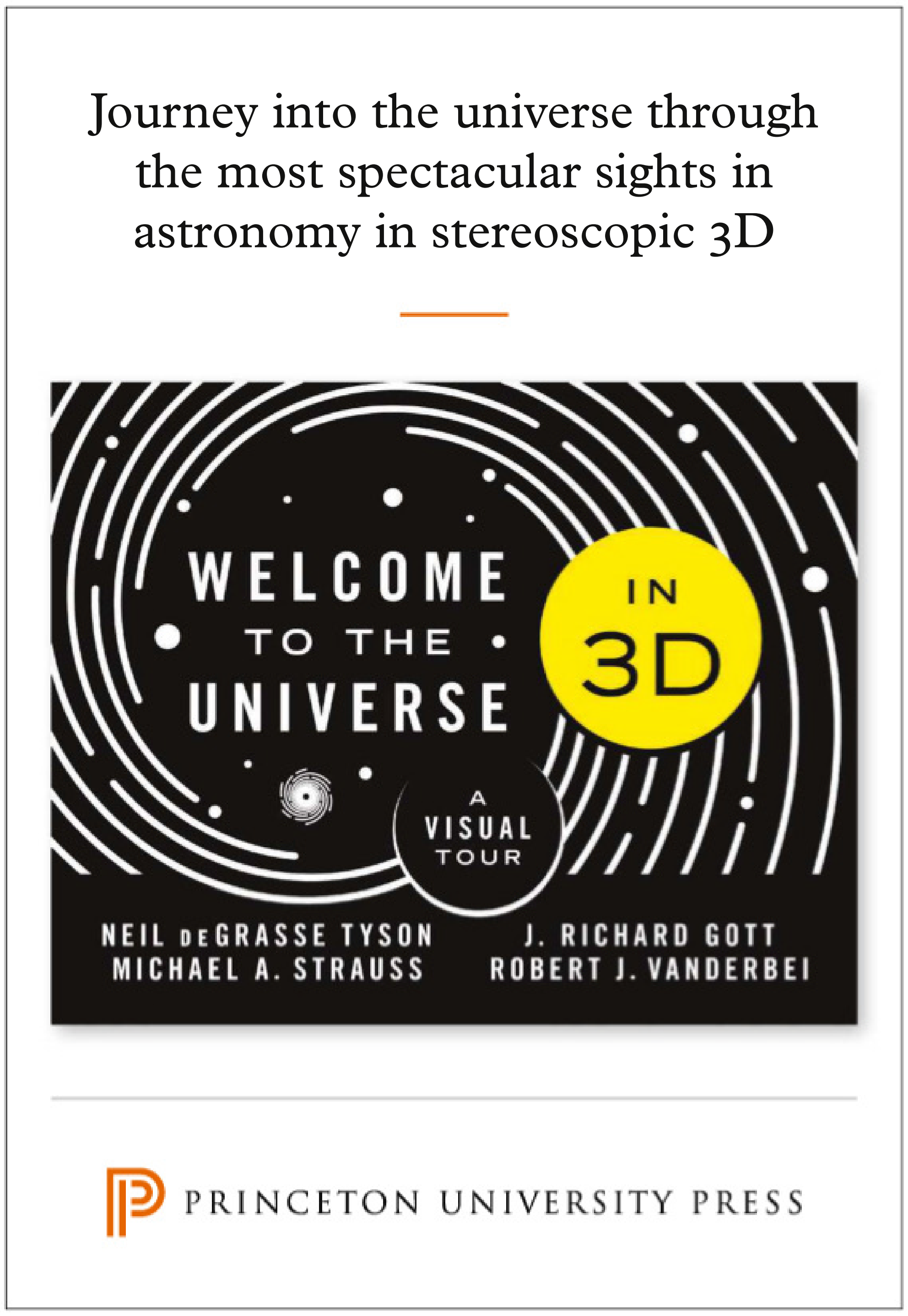
Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE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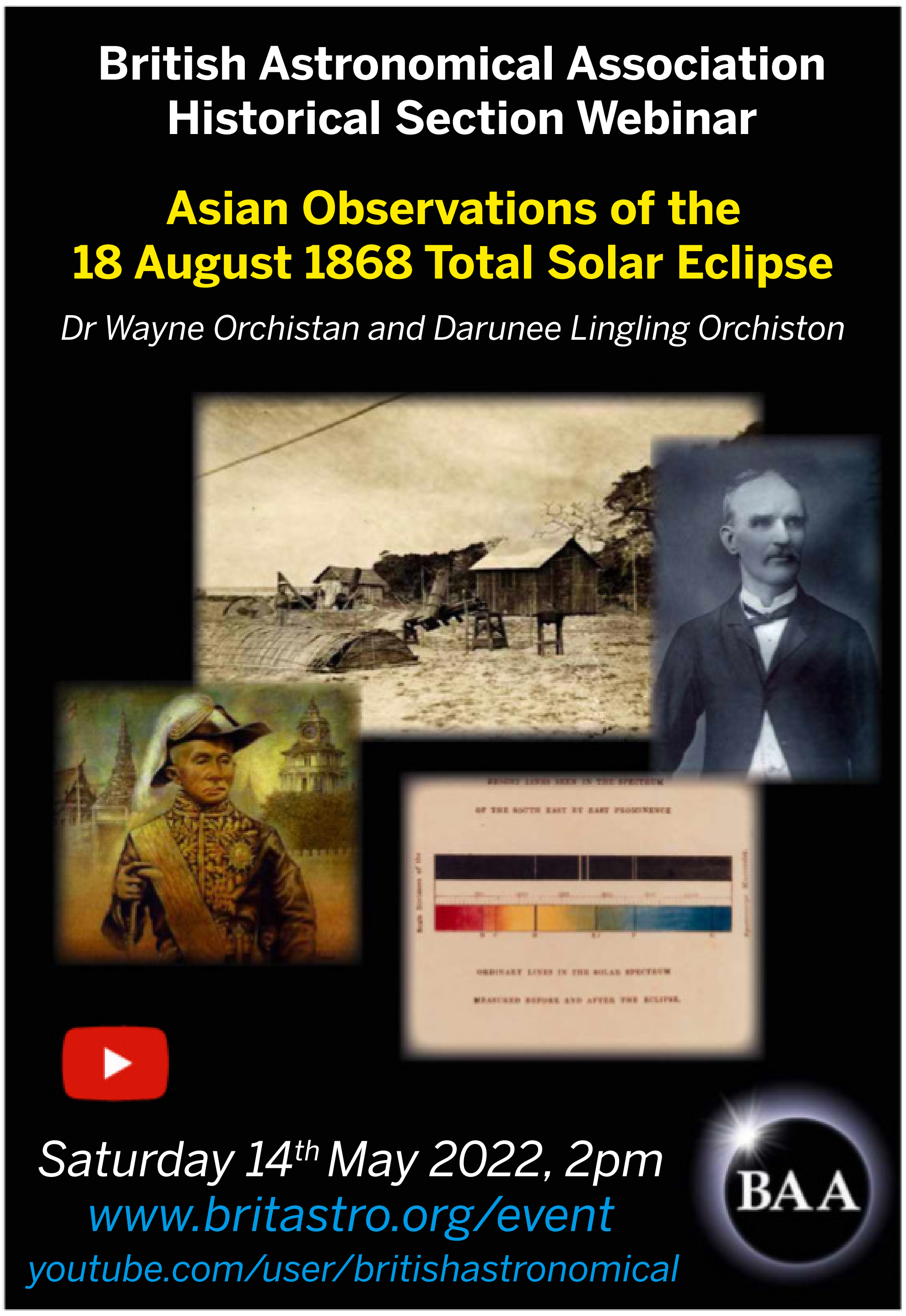
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Asian Observations of the
18 August 1868 Total Solar Eclipse
Dr Wayne Orchistan and Darunee Lingling Orchiston
Saturday 14th May 2022, 2pm
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We can only see dark matter from its effect on stars and galaxies. Here, astronomers used the images of galaxies distorted by gravitational lensing to map out the dark matter, shown in blue

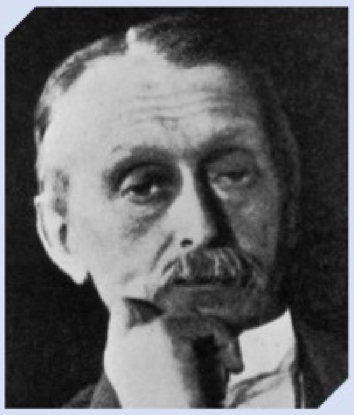
PIONEERS OF DARK MATTER

The term 'dark matter' was coined a century ago this month. **Govert Schilling** selects seven scientists who shed light on astronomy's biggest mystery

Dark matter is what makes the Universe tick. It represents 85 per cent of the material content of our cosmos. Through its gravity, it has enabled the formation of cosmic structure, and it keeps galaxies and galaxy clusters from flying apart. Astronomers have mapped dark matter's distribution by studying gravitational lensing – the bending of starlight by massive objects in space – but no one has ever seen the mysterious stuff, as it doesn't emit, absorb or reflect light. In this article we take a look at seven of the leading voices who helped progress the quest to understand dark matter.

JACOBUS KAPTEYN (1851–1922)

The originator of the term 'dark matter'



Dutch astronomer Jacobus Kapteyn made an early mention of the term 'dark matter' in his *Astrophysical Journal* paper on the structure of our Milky Way Galaxy. The paper was published on 1 May 1922, a few weeks before Kapteyn died.

One of 15 children, young Jacobus was raised in a private boarding school run by his parents. In 1878, he was appointed professor of astronomy at the University of Groningen, but he lacked the money to buy a proper telescope. Instead, he joined forces with Scottish astronomer David Gill, who photographed the southern sky from Cape Observatory in South Africa.

Using a manual plate-measuring machine, Kapteyn spent five-and-a-half years meticulously measuring the positions of 454,875 individual stars – an impressive undertaking that led to the *Cape Photographic Durchmusterung* (CPD) – the largest and most accurate stellar catalogue of the time.

Later, Kapteyn studied the structure of the Milky Way, working with American astronomer George Ellery Hale at Mount Wilson Observatory in California. In his final paper, he presented a model that is now known as the 'Kapteyn Universe': a relatively small Milky Way with the Sun close to its centre, and nothing beyond its outer edge.

Although this model would turn out to be completely wrong, Kapteyn realised that studying the motions of stars would reveal the total mass of the system. In his May 1922 paper he wrote: "It is incidentally suggested that when the theory is perfected it may be possible to determine the amount of dark matter from its gravitational effect." The riddle of dark matter was born. ▸

▼ The Kapteyn Universe, 1922, in which he looked at the motions of stars to study the Milky Way's total mass

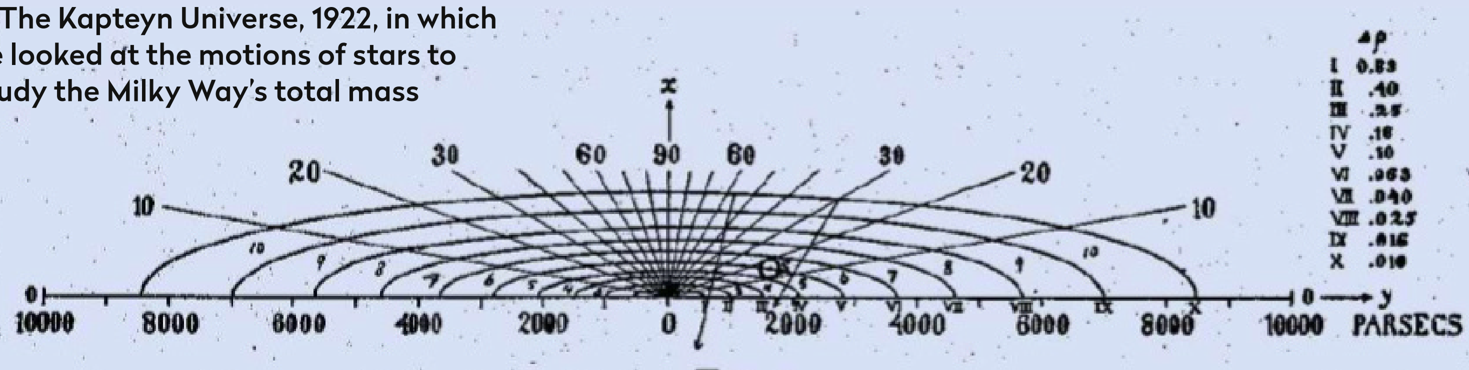
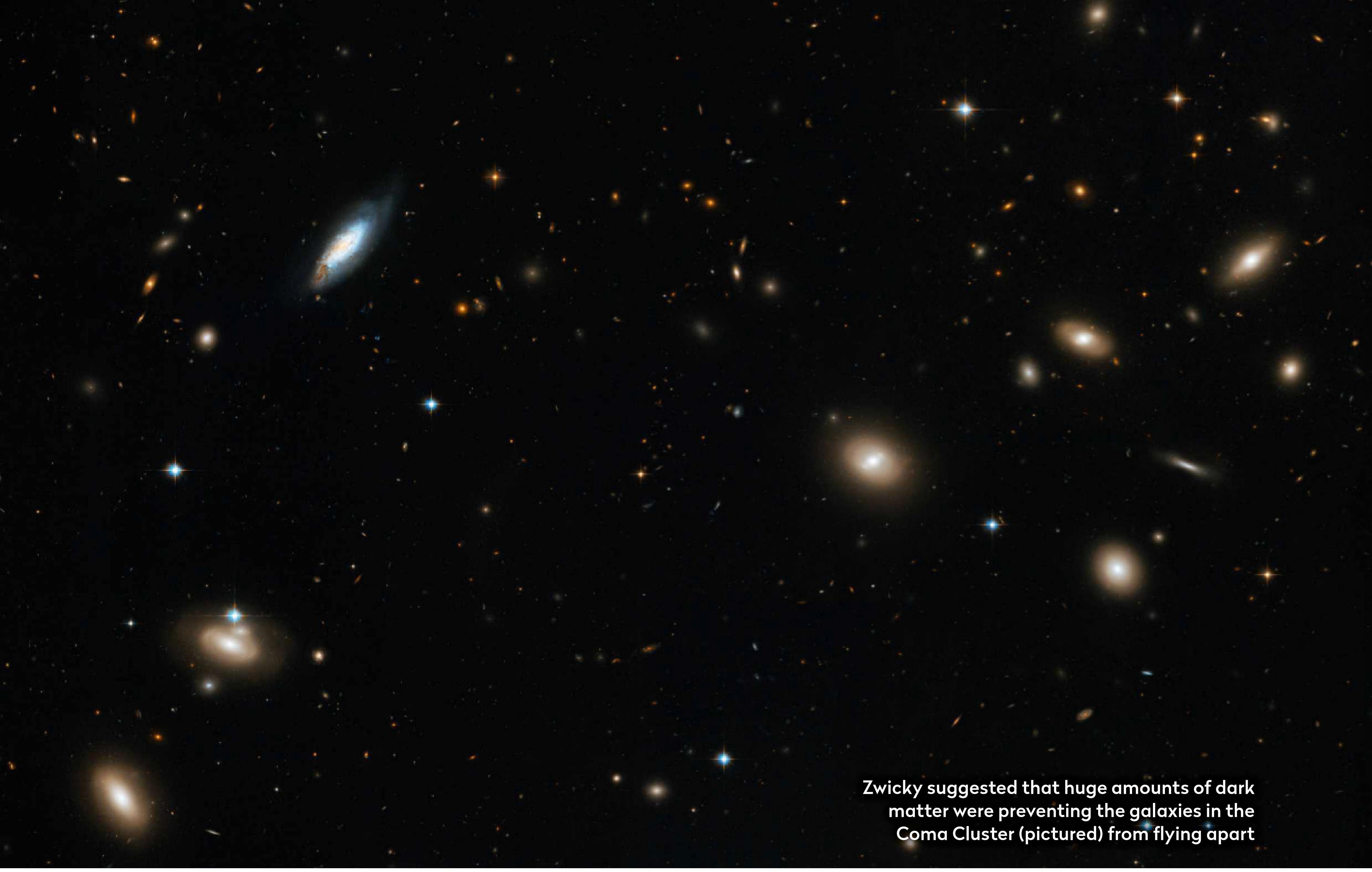


FIG. I



Zwicky suggested that huge amounts of dark matter were preventing the galaxies in the Coma Cluster (pictured) from flying apart

FRITZ ZWICKY (1898–1974)

Realised that galaxies must be more massive than they appear

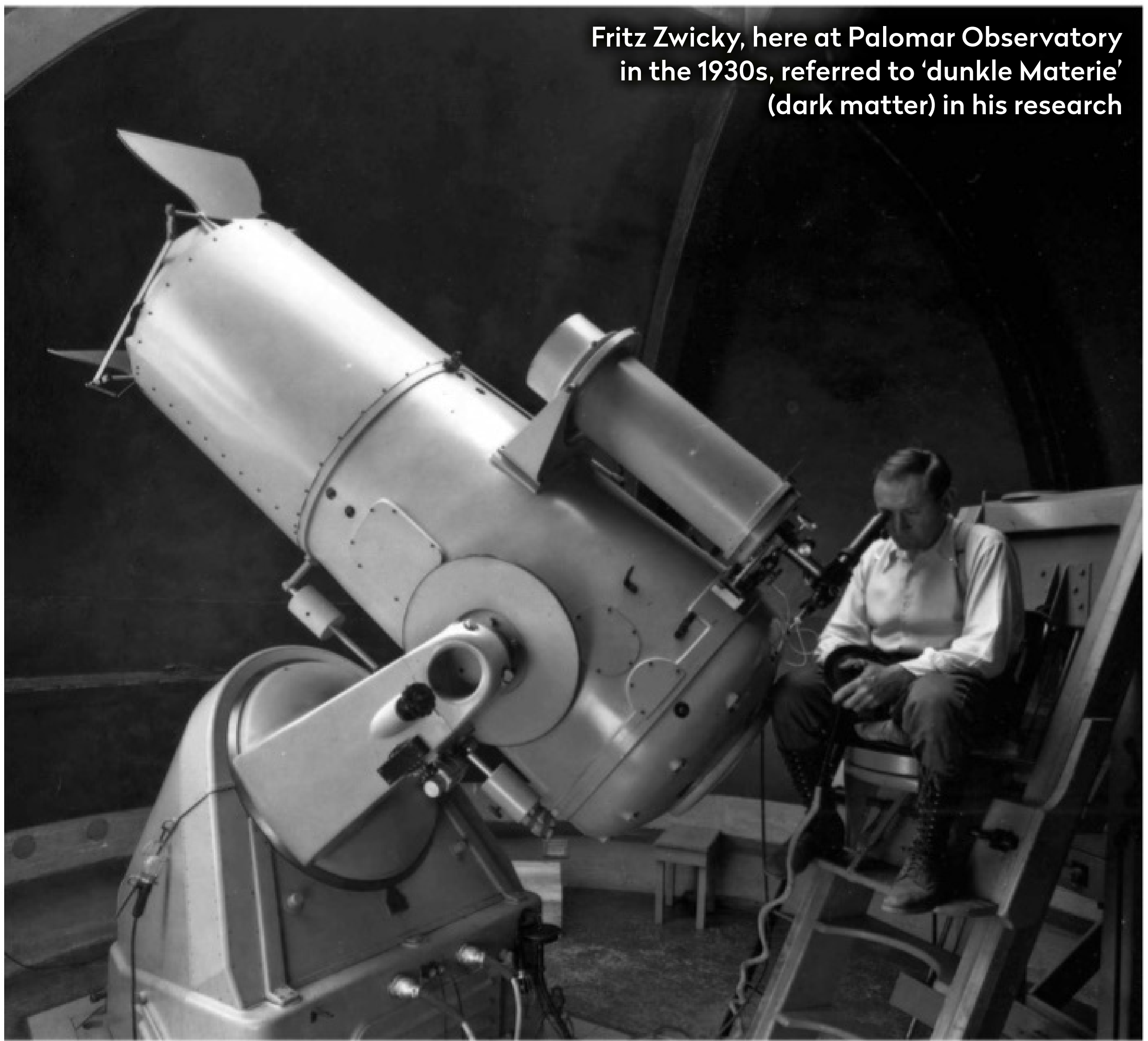
Born in Bulgaria to Swiss parents, Fritz Zwicky moved to the US at the age of 27 to assist Nobel scientist Robert Millikan in his studies of solid state physics at the California Institute of Technology. That same institute was home to eminent astronomers like George Ellery Hale, Edwin Hubble and Walter Baade. Before long, Zwicky got hooked on astronomy, and became a stellar hot shot himself, studying supernovae and predicting the existence of neutron stars together with Baade.

Using Mount Wilson's 2.5m Hooker Telescope, he clocked the velocity of individual galaxies in the Coma Cluster, by measuring their Doppler effect – a minute change of wavelength in the galaxy's light. The observed velocity spread within the cluster is a measure of the total mass of the cluster.

It turned out that the Coma galaxies were moving much faster than expected on the basis of the cluster's visible content. To prevent the cluster from flying apart, it would need huge amounts of invisible mass – 'dunkle Materie' (dark matter), as Zwicky wrote in his 1933 paper in a rather obscure Swiss magazine.

Similar results for our own Galaxy had been obtained a year earlier by Kapteyn's student Jan Oort (of Oort Cloud fame). And later work by Sinclair Smith at Mount Wilson on the Virgo Cluster led to the same conclusion.

Surprisingly, the dark matter riddle was largely neglected by the astronomical community for a couple of decades.



Fritz Zwicky, here at Palomar Observatory in the 1930s, referred to 'dunkle Materie' (dark matter) in his research

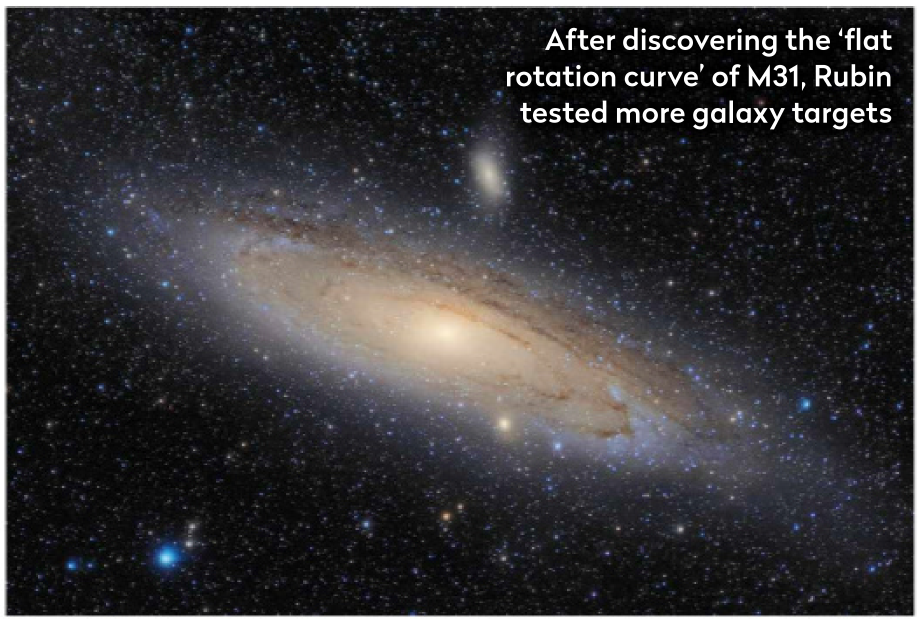
VERA RUBIN (1928–2016)

Measured the outskirts of galaxies and found they spin as fast as their centres

As a child, Vera Rubin loved watching the stars. But in 1948, Princeton University still didn't allow female astronomy graduate students, so she went to Cornell University instead and obtained her PhD at Georgetown University. There, she got a job at the Carnegie Institution of Washington's Department of Terrestrial Magnetism, where she met instrument builder Kent Ford, who was developing an electronic image tube that would allow the spectroscopic study of faint astronomical objects.

Starting in late 1966, Rubin and Ford regularly drove all the way to Arizona to make spectral measurements of individual glowing gas clouds in the Andromeda Galaxy, mounting the bulky image tube on telescopes at Lowell Observatory, near Flagstaff, and at Kitt Peak National Observatory, near Tucson. They presented their first results at an American Astronomical Society (AAS) meeting in December 1968.

Over the next decade, it became ever more clear that Andromeda has a 'flat rotation curve': the outer parts of the galaxy rotate as fast as the inner parts, whereas our understanding of gravity says the outer regions should rotate slower if the stars are the only masses present. This suggested there was more to the galaxy than met the eye. "The conclusion is inescapable that non-luminous matter exists beyond the optical galaxy," Rubin and Ford wrote in an *Astrophysical Journal* paper in 1980, together with Norbert Thonnard.



After discovering the 'flat rotation curve' of M31, Rubin tested more galaxy targets

At the time of Rubin's death in 2016, Princeton astrophysicist Neta Bahcall called her "the mother of flat rotation curves and dark matter". Rubin herself never failed to mention the very important supporting observations by radio astronomers, who arrived at the same conclusion.

JAMES PEEBLES (1935–)

Discovered the early Universe doesn't match up with what we see today

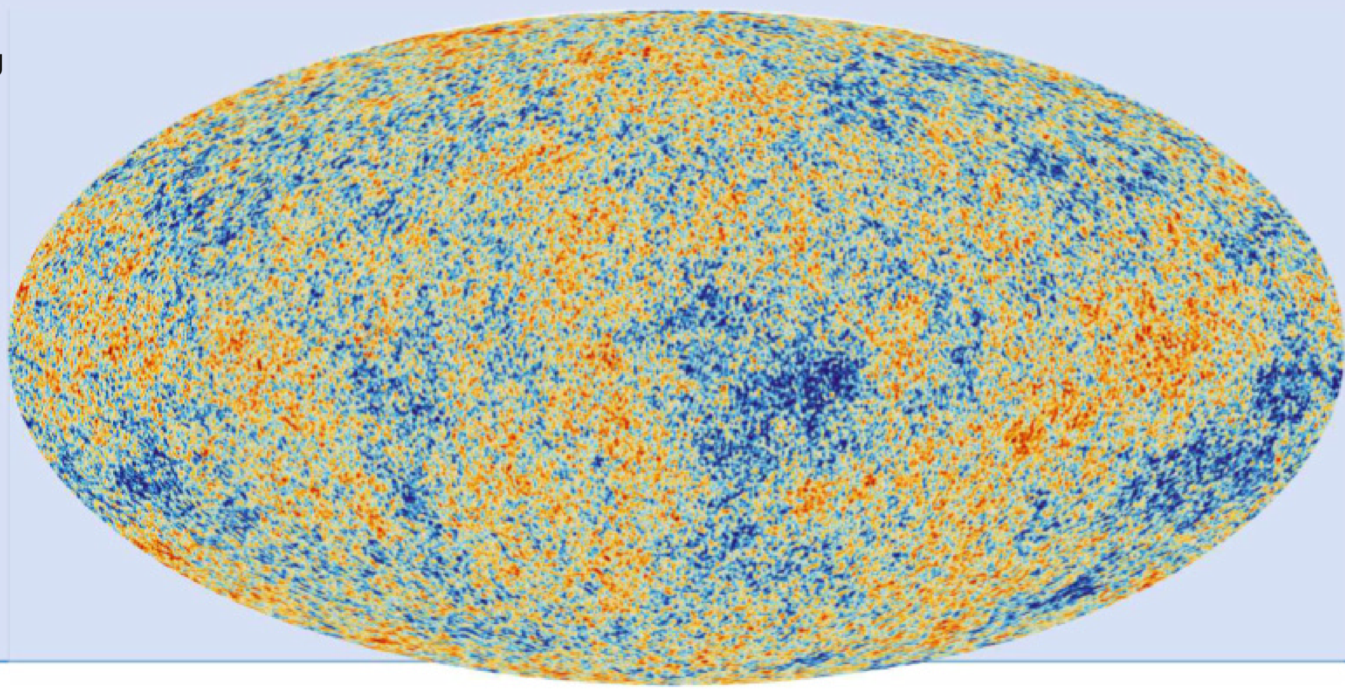
Born in Winnipeg, Canada, James Peebles has been at Princeton University since 1958. He was the founder of what is now known as 'physical cosmology' – studying the birth and evolution of the Universe though theoretical physics.

In 1973, along with fellow Princeton astrophysicist Jerry Ostriker, Peebles showed that disc galaxies like our Milky Way or Andromeda cannot be stable unless they are embedded in giant halos of dark matter. The two scientists, together with Israel's Amos Yahil, also made the first reliable estimate of the mass density of the Universe in 1974.

Peebles studied the cosmic microwave background (CMB) – a relic of the Big Bang – as this could show him if the small fluctuations in the matter density of the primordial Universe are what would gravitationally evolve into the galaxy clusters and superclusters we see today.

His solution: dark matter has to be cold (eg consisting of relatively slow-moving particles), and should hardly experience any interaction with 'normal' (so-called baryonic) matter, other than through gravity. In that case, clumps of dark matter could start to form before the CMB was released. At a later stage, gas would fall into these gravitational wells, leading to the structured Universe we see today. ▸

▼ **From studying the CMB, Peebles found dark matter was 'cold' or slow-moving**



SANDRA FABER (1944–)

Collected comprehensive evidence that dark matter was real

In the early 1970s, Harvard PhD student Sandra Faber temporarily worked at Carnegie's Department of Terrestrial Magnetism in Washington, DC, where she learned about the rotation curve measurements of Rubin and Ford. She studied elliptical galaxies and discovered that these too appear to be embedded in dark matter halos.

After moving to the University of California at Santa Cruz, Faber, together with John Gallagher, wrote a hugely influential review article about dark matter for *Annual Reviews of Astronomy and Astrophysics*, published in 1979. By presenting all the available evidence, the two authors convinced the scientific community that dark matter was not just a figment of our imagination, but a real, major constituent of the Universe.

Five years later, in 1984, Faber was co-author of yet another landmark paper, this time in *Nature*. With George Blumenthal, Joel Primack and Martin Rees, she described the evolution of a cold, dark matter-dominated Universe. The paper provided a detailed description of the formation of globular star clusters, galaxies and galaxy clusters, and even discussed possible candidates for James Peebles's 'cold dark matter'.

Faber discovered galaxies are surrounded by clouds – or halos – of dark matter

"We have shown that a universe with [approximately] 10 times as much cold dark matter as baryonic matter provides a remarkably good fit to the observed Universe," the authors wrote, concluding that the cold dark matter picture "seems to be the best model available and merits close scrutiny and testing".

CARNEGIE INSTITUTION FOR SCIENCE, NASA/ESA/JPL-CALTECH/YALE/CNRS, ELENA APRILE/ COLUMBIA UNIVERSITY, XENON COLLABORATION, JOHANNES SCHEDLER/CCDGUIDE.COM, WEIZMANN INSTITUTE OF SCIENCE, HINDAWI

ELENA APRILE (1954–)

Looks for dark matter not in the sky, but deep underground

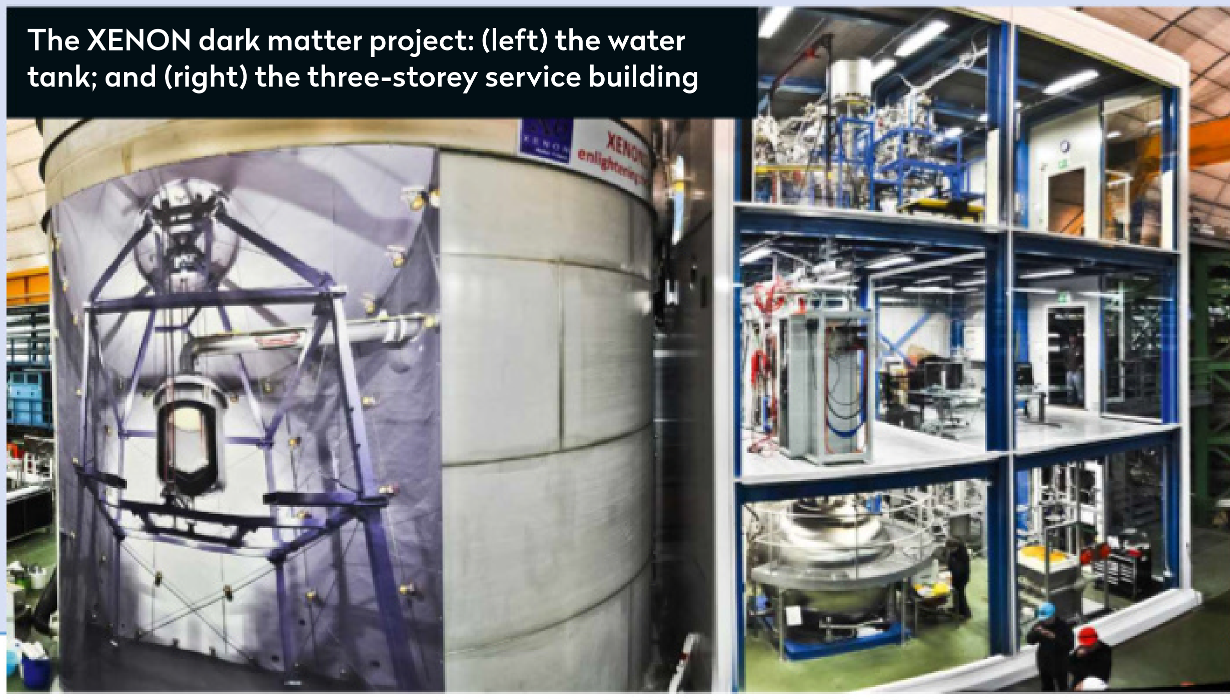
Italian physicist Elena Aprile was born in Milan, worked at CERN (the European particle physics laboratory near Geneva), and moved to the US in 1983. At Columbia University in New York, she helped to build balloon experiments that used noble gases like argon and xenon to detect these particles, neutrinos and gamma rays.

When, in 2011, she learned about the British ZELPIN-experiment in the Boulby Mine in Yorkshire – a xenon-based detector to search for dark matter particles – she switched gears and started her own dark-matter experiment, working with Brown University's Richard Gaitskell, among others.

In 2010, the group's first full-scale detector was installed in the Gran Sasso Tunnel, in the Italian Apennines, shielded from cosmic rays and other possible disturbances. Over the past decade, Aprile's team has constructed ever larger and more sensitive versions of their detector. (Gaitskell now leads his own US project in an old gold mine in South Dakota.)

XENONnT, as the current version of the detector is called, became operational last year. Like its predecessors, it searches for the tiny flashes of light that are produced when a dark matter particle slams into a xenon nucleus – a very rare interaction.

So far, no convincing dark matter signal has been observed, but Aprile doesn't give up. Plans for an even larger experiment, called Darwin, are on the drawing board.

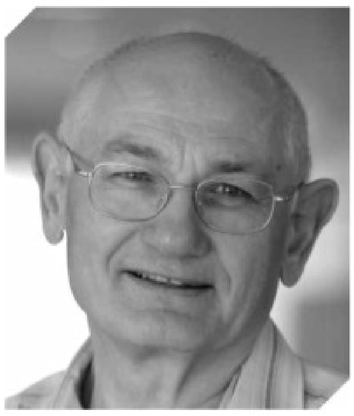


The XENON dark matter project: (left) the water tank; and (right) the three-storey service building

By studying the decline in gravitational forces in the outer parts of a spiral galaxy like NGC 2403 (pictured), scientists can challenge theories of dark matter

MORDEHAI MILGROM (1946–)

Questioned whether we really do need dark matter after all

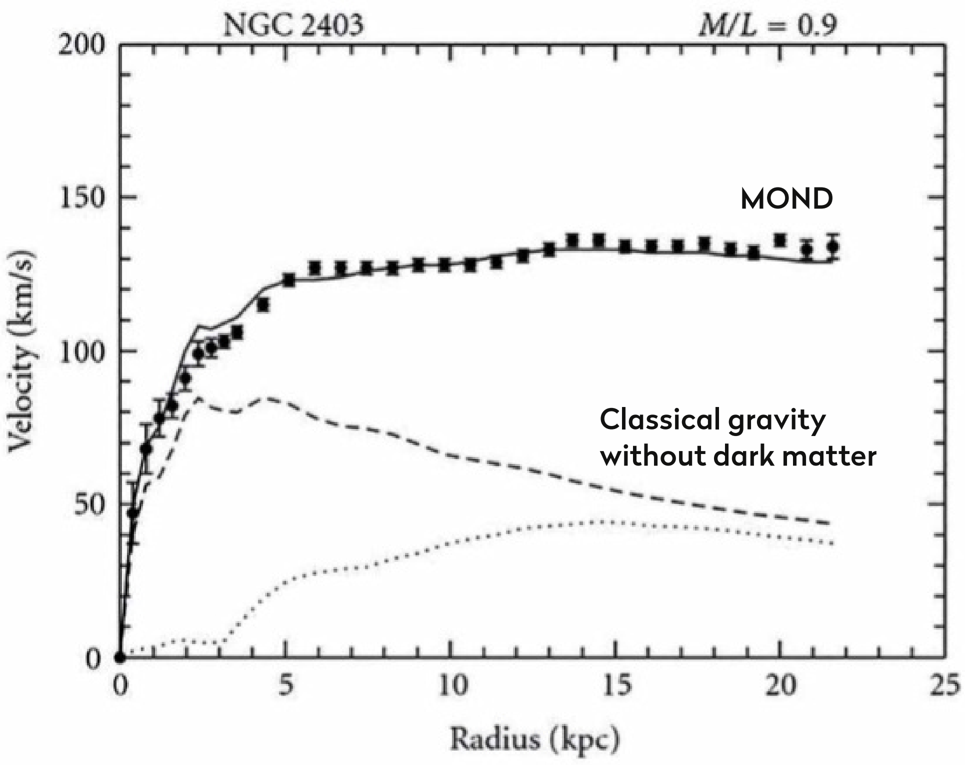


When Israeli particle physicist Mordehai Milgrom visited Princeton in 1980, he learned about flat rotation curves and the riddle of dark matter for the first time. But instead of theorising about hypothetical particles, Milgrom asked himself: What if our ideas about gravity are wrong?

In the summer of 1983, he published his MOND theory (Modified Newtonian Dynamics) in *The Astrophysical Journal*. According to MOND, the strength of the gravitational force declines at a much slower rate with distance (not as $1/r^2$, but as $1/r$) in weak gravity environments, like the outer parts of galaxies. This relatively simple (albeit rather ad hoc) adaptation of Newton's laws perfectly explains the flat rotation curves found by Rubin, Ford and their radio astronomy colleagues, without any need for mysterious dark matter.

Despite many attempts, no one has yet been able to falsify MOND, which is not to say that the theory doesn't face any problems. For example, Milgrom and his followers still need at least some (baryonic) dark matter in clusters of galaxies, and they haven't fully succeeded in formulating an elegant 'relativistic' version of their theory.

Nevertheless, MOND's successes in explaining galactic rotation curves are impressive and Milgrom could possibly be on to something. If so, our century-long search for dark matter may have been unrealistic, and Milgrom might end up in the astronomy history books as the pioneer of a new era in our understanding of the Universe. Only time will tell.



◄ The rotation curve of galaxy NGC 2403. Milgrom was able to fit the square data points almost perfectly using MOND (Modified Newtonian Dynamics) without the need for dark matter

Govert Schilling's book *The Elephant in the Universe* is published on 31 May by Harvard University Press

Learning about LAYERS

Expert astrophotographer **Will Gater** provides a beginner's guide to the power of layers-based image editing

As any astrophotographer will tell you, the cold nights that are spent out capturing data – whether for a simple DSLR camera nightscape or a multi-hour deep-sky masterpiece – are only the opening stages of a long journey to produce a final image. An enormous amount of work goes into the processing of even quite a simple data set. We may think of stacking and calibration software programs – like DeepSkyStacker or Nebulosity – when we hear the phrase 'astro-image processing', but often much of this work is done in Photoshop or GIMP too – certainly more than a few final tweaks.

These programs allow you adjust different aspects of an image (like the brightness, contrast and colour balance), but they're also important in another respect, as they are what's known as 'layers-based' editors. This means that multiple images, or sets of image data, can be brought into these programs as separate layers.

You can think of regular image-editing programs as being similar to the process of painting, where each daub of new paint is added to the canvas, changing the overall image. But a layers-based editor allows multiple, individual layers to simultaneously combine to make the image on screen. Each of these also can be tweaked, adjusted, masked, aligned or blended in myriad ways while processing.

Because each image layer can be switched on or off, and has different treatments or processing techniques applied to it in isolation, it's easy to vary its contribution to the overall picture, or even delete its effect completely. In the painting analogy this is akin to having the ability to remove, tweak or even change the hue of paint strokes that have already been applied to the canvas.

In a non layers-based editor, to go back and tweak an adjustment to part of the image, like a brightness boost or a curves enhancement, you will often need to restart the editing process, if such alterations are possible in the first place.

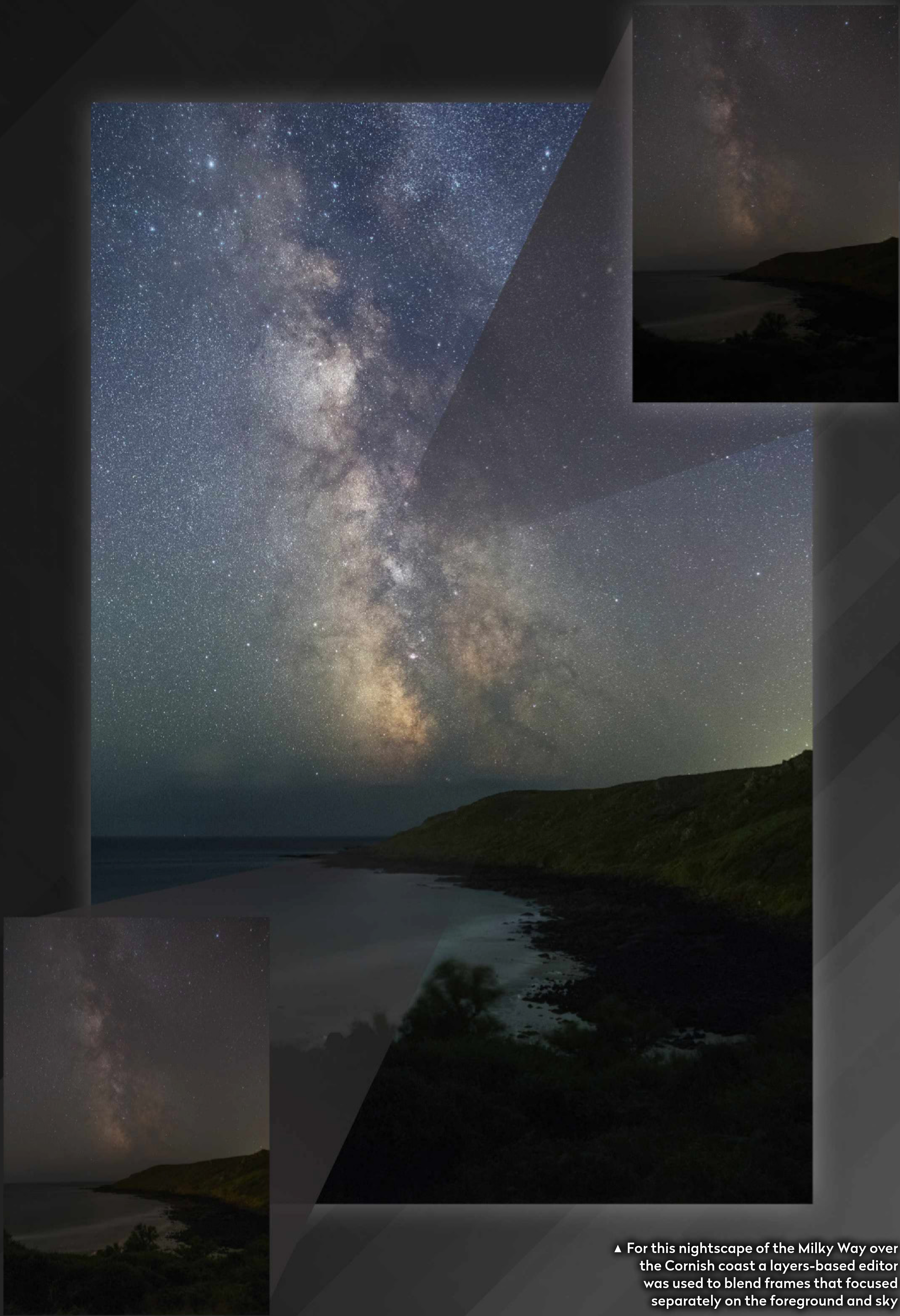
Abundant applications

For astrophotographers, the practical applications of layers-based image editors are numerous. A basic example is the creation of manually stitched lunar mosaics. In such projects tens, if not hundreds, of frames – with different 'footprints' of the Moon's surface – can be loaded as individual layers into a large digital 'canvas'. Layers-based editing then allows them to be manually manipulated, aligned and blended to create a composite of the lunar disc, or a highlighted section.

Another common use of layers-based image editing in astrophotography is to blend two or more exposures, or images with different processing treatments or filters applied. This is often done with nightscapes and long-exposure, deep-sky imaging of bright targets.

In this article we will look at three introductory examples of how to use a layers-based editing programme in the scenarios above. We will only scratch the surface of what's possible with these techniques; there are many more applications. These include high-pass filtering, creating animated GIFs, image stacking and blending, and even adding annotations to your images. Once you start using layers-based software your astrophoto processing workflow won't be the same again! ►

GETTY, WILL GATER



▲ For this nightscape of the Milky Way over the Cornish coast a layers-based editor was used to blend frames that focused separately on the foreground and sky

Case study 1

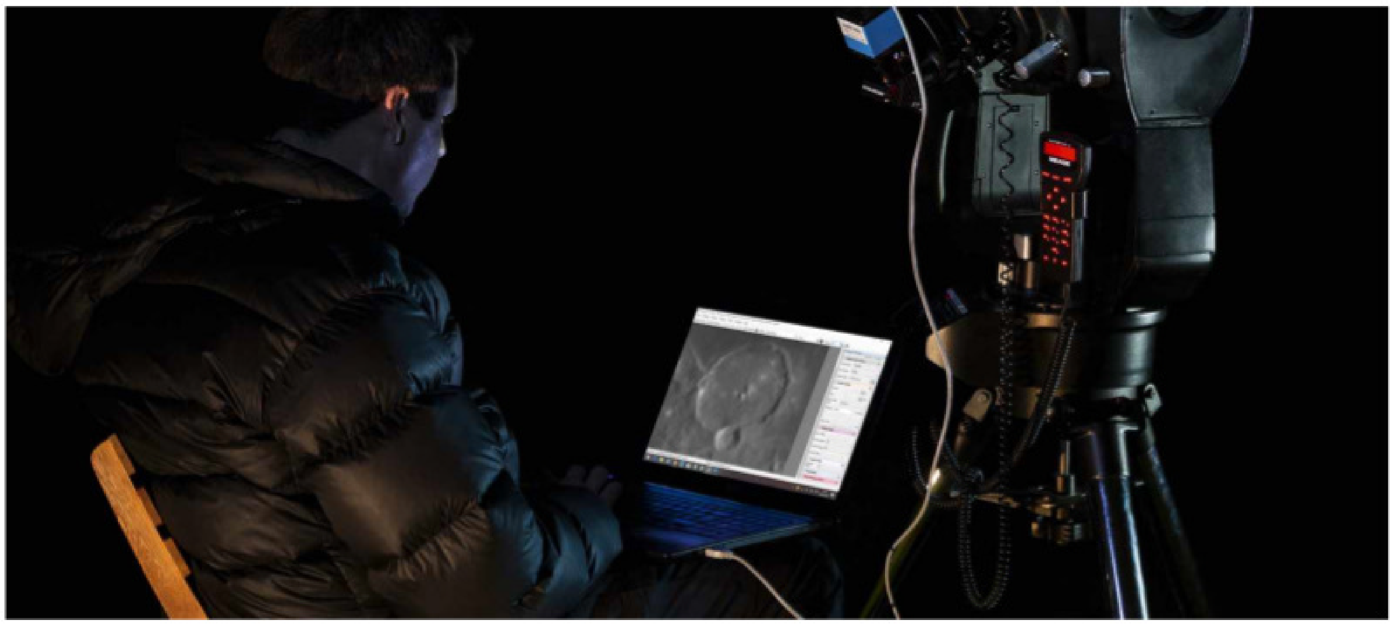
Creating a manually stitched lunar mosaic

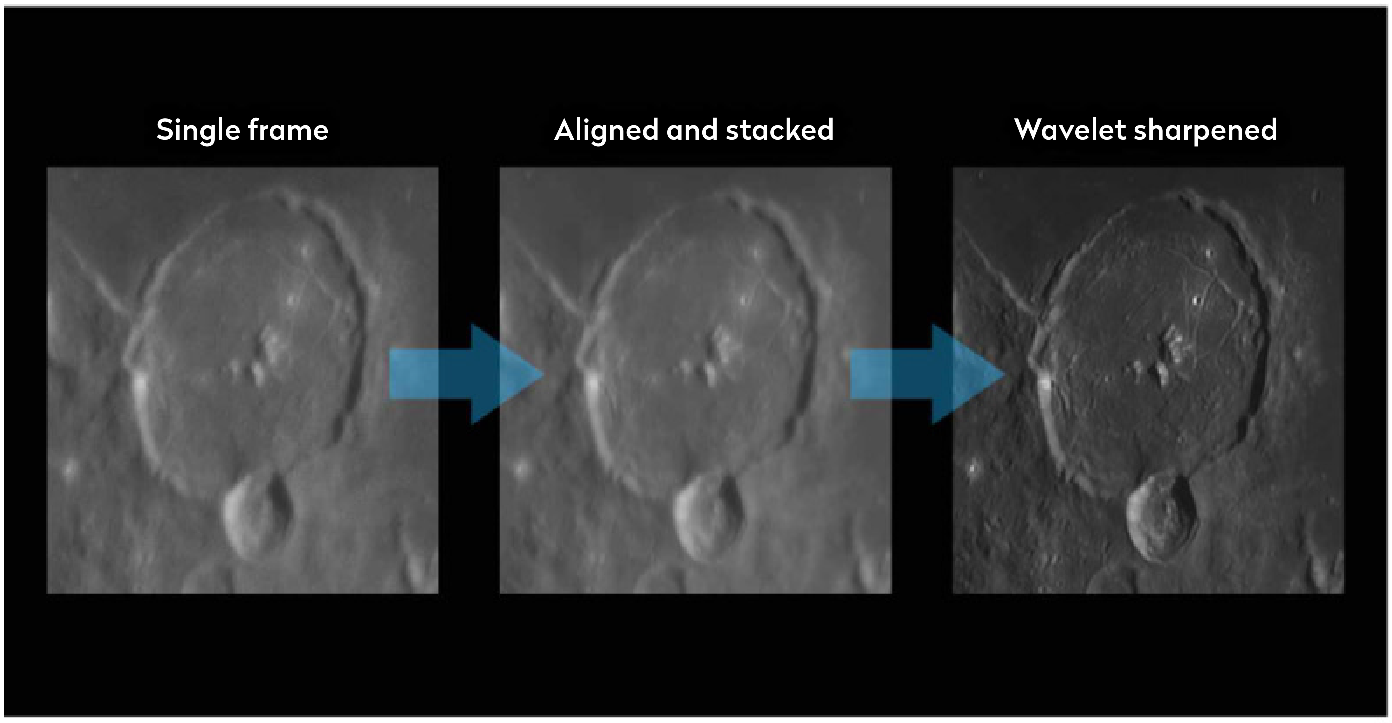
Making a lunar mosaic from scratch is a great way to introduce yourself to the basic mechanics of layers-based editing. Such mosaics are created by combining multiple, overlapping images of the Moon's surface. While there are plug-ins and software that can do this automatically, manual composition in a layers-based program gives you full control over the process. In this example we will assume the individual frames begin life as video captures taken through a high frame rate camera and telescope.

A wide-field mosaic of the region around the crater Gassendi (above), stitched together manually in a layers-based editor

STEP 1 CAPTURING THE FRAMES

Don't just think about focusing and exposure, but also about creating the best possible data for manual composition. Give each video capture an overlap between neighbouring frames, as this makes it easier to match and align. Monitor how well your mount is tracking: if it's not keeping the framing stable, thin gaps can creep into the final mosaic.





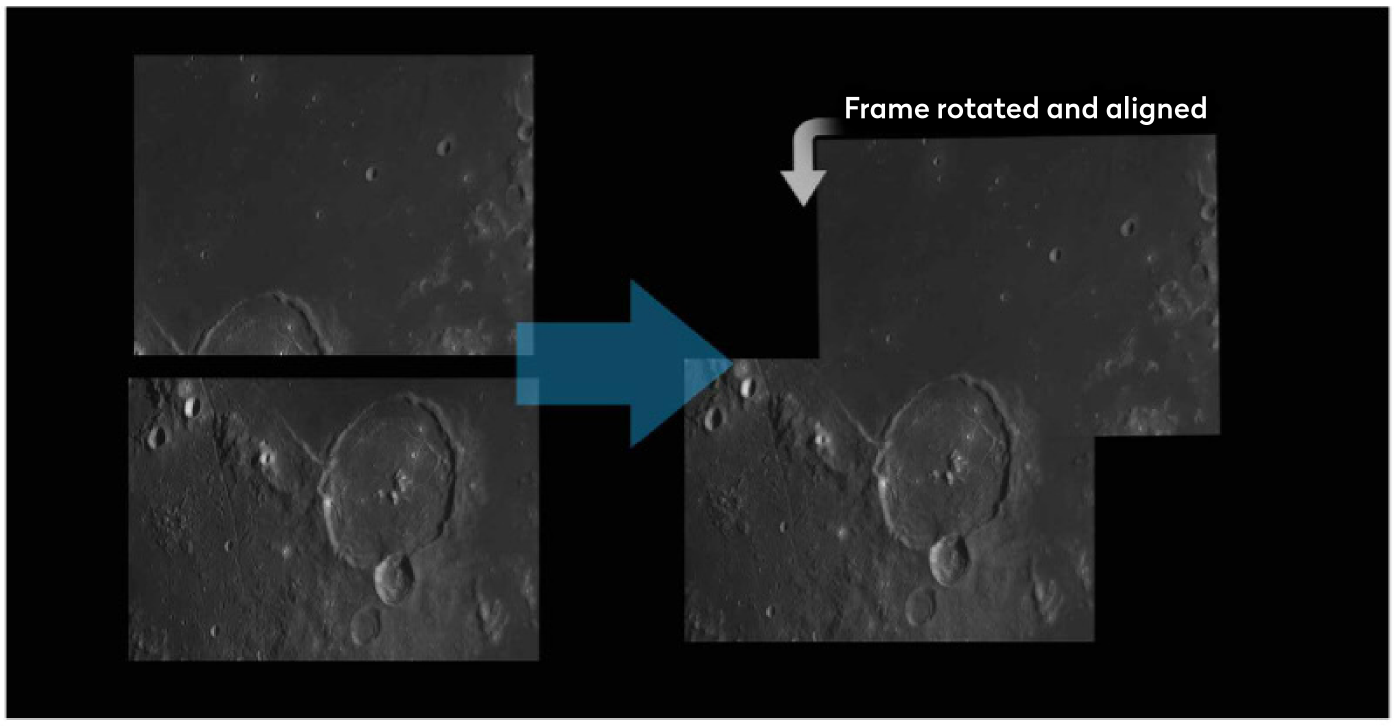
STEP 2 PREPARING THE DATA FOR MOSAICING

You can now process the videos from Step 1. First, open a video in alignment and stacking software such as the free AutoStakkert! Under 'Image Stabilization' (IS) be sure to select 'Expand' as this will ensure there's space around the edge that we can make use of. Once AutoStakkert! has done its work, open the images in the free software RegiStax and apply gentle wavelet sharpening (left) before saving each file as a PNG.

ALL PICTURES: WILL GATER

STEP 3 START ALIGNING FRAMES IN THE LAYERS-BASED EDITOR

Now import all of your frames into the editor. In Photoshop this can be done by selecting 'File › Scripts › Load Files into Stack', while in GIMP it's 'File › Open as Layers'. Select the first two frames of your imaging sequence and start aligning them. In Photoshop you can move and rotate a layer using the 'Move Tool', while in GIMP you'll have to use a combination of the 'Move Tool' and 'Rotate Tool'.

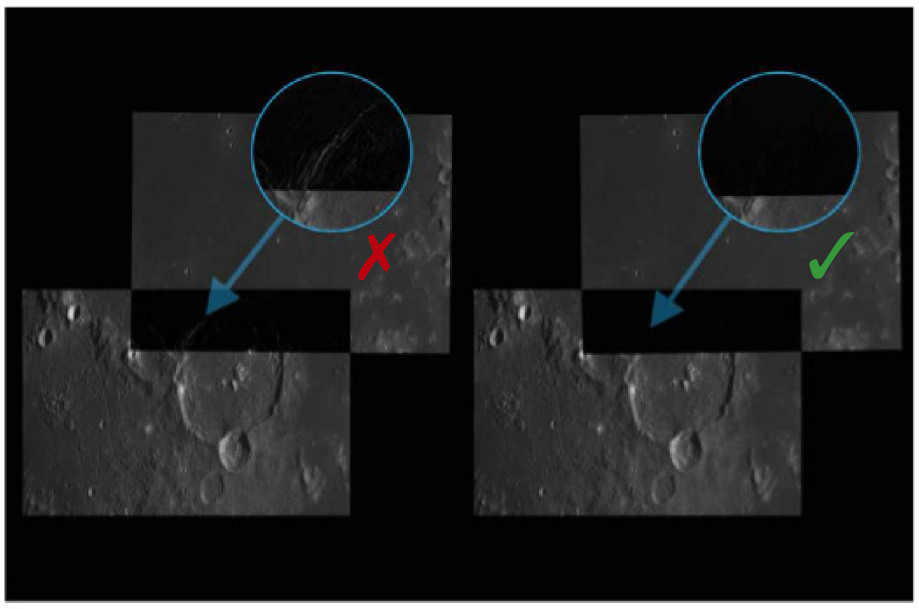


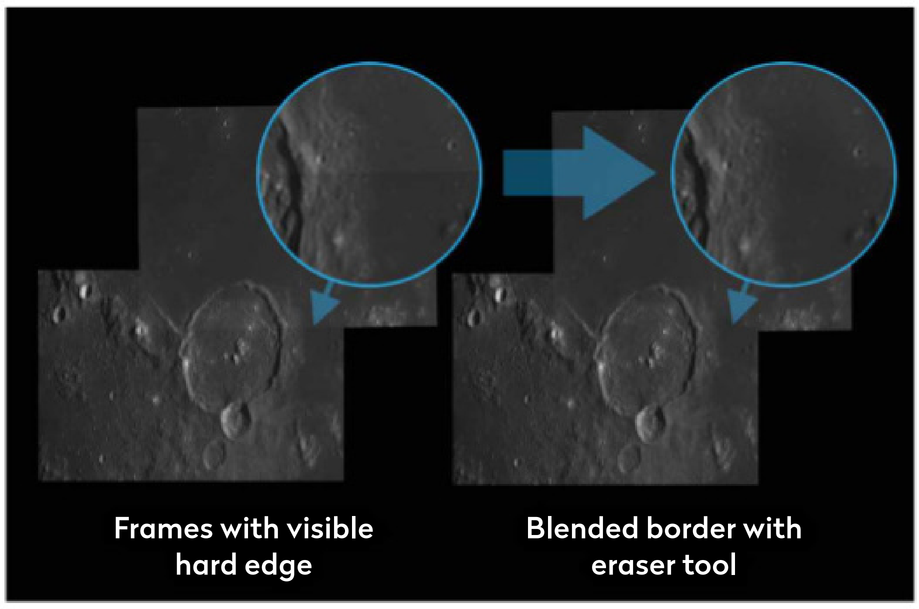
STEP 4 EXAMINE THE QUALITY OF THE ALIGNMENT

Check the rotational and positional accuracy of the alignment. You can do this by examining the 'Difference' image of the two frames by setting the upper layer's blending mode to 'Difference' in the 'Layers' menu. The closer the pixels in the 'Difference' layer match with those below, the nearer to solid black they'll appear, making slight offsets noticeable. Use the arrow keys to nudge the frames, then switch back to 'Normal' blending when you're done.

STEP 5 BRING IN ANOTHER LAYER AND REPEAT THE PROCESS

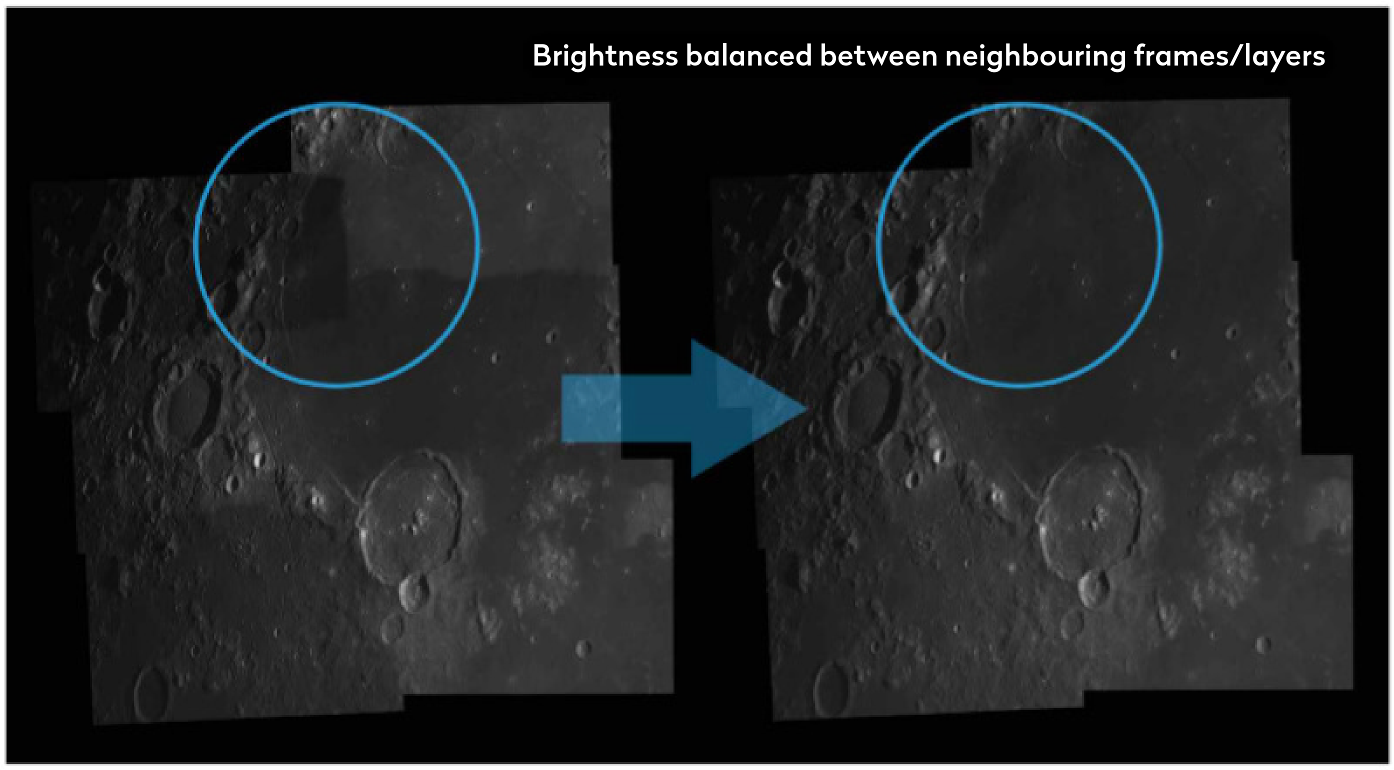
Now repeat some of the earlier steps by selecting another layer and aligning it to the co-aligned first and second frames. This will, of course, have to be done in sequence for all frames in their separate layers. If you notice a hard edge between frames – or frames that show poorer quality data than the one(s) underlying them – you can use a soft-edged eraser tool to remove it.





STEP 6 BALANCE LIGHTING BETWEEN FRAMES IF NECESSARY

The last task – before blending the image into a final, single composite that can be sharpened and tweaked further – is to even out any differences in brightness between frames that sit next to each other. Do this by making very small tweaks to the brightness and contrast of an individual layer, for example using the 'Levels' tool via 'Colours › Levels' in GIMP and 'Image › Adjustments › Levels' in Photoshop. ▸



Case study 2

Blending data in nightscapes using a layer mask

There are many ways in which layer-based editors are useful when you are processing 'nightscapes'. For example, they can be used to blend two or more images held in separate layers. A common example of this in nightscape imaging is when you are bringing two different exposures together, or perhaps two treatments of the same data.

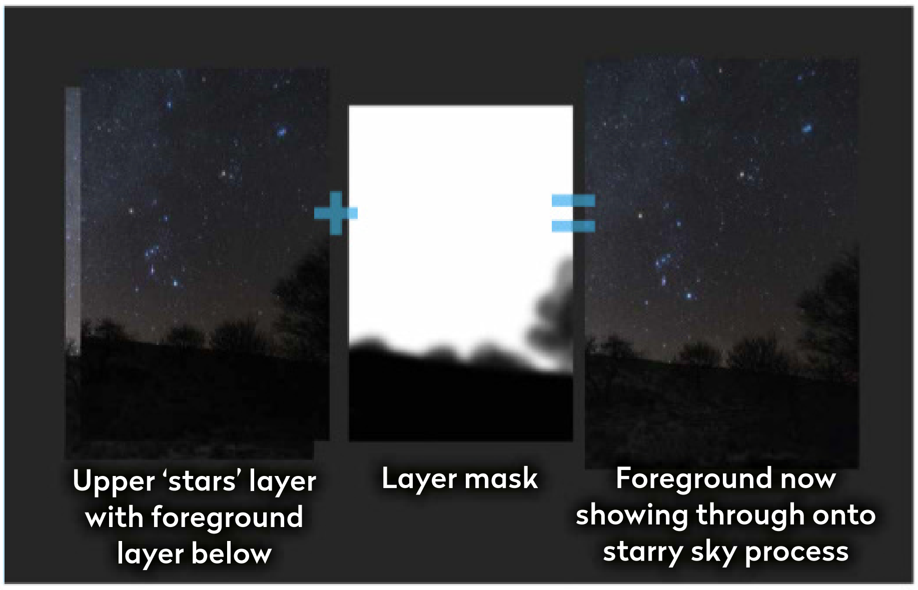
Here, we are going to look at how you would do that using what's called a layer 'mask'.

STEP 1 CAPTURE AND PROCESS THE TWO FRAMES YOU WANT TO BLEND

First capture and process the two images you want to blend. This could be one long exposure (or multiple stacked ones) at a low ISO for the foreground and a shorter one for the sky. It could also be two images made from just one exposure: one processed to bring out details in the starry sky and another, using the same data, where you've focused on brightening the foreground, eg with a curves enhancement. You can apply noise-reduction filters or vignetting calibration now, but don't make levels or curve stretches too harsh at this stage.

STEP 2 BRING THE IMAGES TOGETHER INTO TWO LAYERS

Take one image and place it into a new layer in the other. In Photoshop click on 'Select › All', then 'Edit › Copy Merged', before pasting into the other image file. In GIMP, click on 'Select › All', 'Edit › Copy Visible', then 'Paste as › New Layer'. Now, align the layers using the techniques discussed in Case Study 1. In some instances, especially if one exposure was taken minutes after the other, there may not be perfect alignment and there will be a small, insurmountable offset of a few tens of pixels due to the sky's motion. Make an alignment and crop areas that don't overlap.



STEP 3 APPLY A LAYER MASK TO BLEND THE LAYERS

Now apply a layer mask to make one layer visible 'through' the other. In our example, the image processed for the stars is the upper layer in the layers window. To add a mask in Photoshop click the black-circle-in-a-white-rectangle icon at the bottom of the 'Layers' window. In GIMP, right-click on the upper layer and click 'Add Layer Mask' and choose the 'White' option. In GIMP you now use a large, diffuse paint brush to 'paint' a mask and reveal the desired area of the underlying layer. In Photoshop you do the same, but with the eraser tool instead.

STEP 4 FINAL ADJUSTMENTS

You should be close to having a final image, with the desired parts of one layer showing through the other. You can now make tweaks to the brightness and contrast of the two layers. Now that you have isolated the different areas with a mask, you can make those adjustments to one layer or the other and can see 'live' how they affect the composition. When you're happy, flatten the image – 'Layer › Flatten Image' in Photoshop, and 'Image › Flatten Image' in GIMP – to merge all the layers and make final global adjustments, eg colour balancing.

ALL PICTURES: WILL GATER

Case study 3

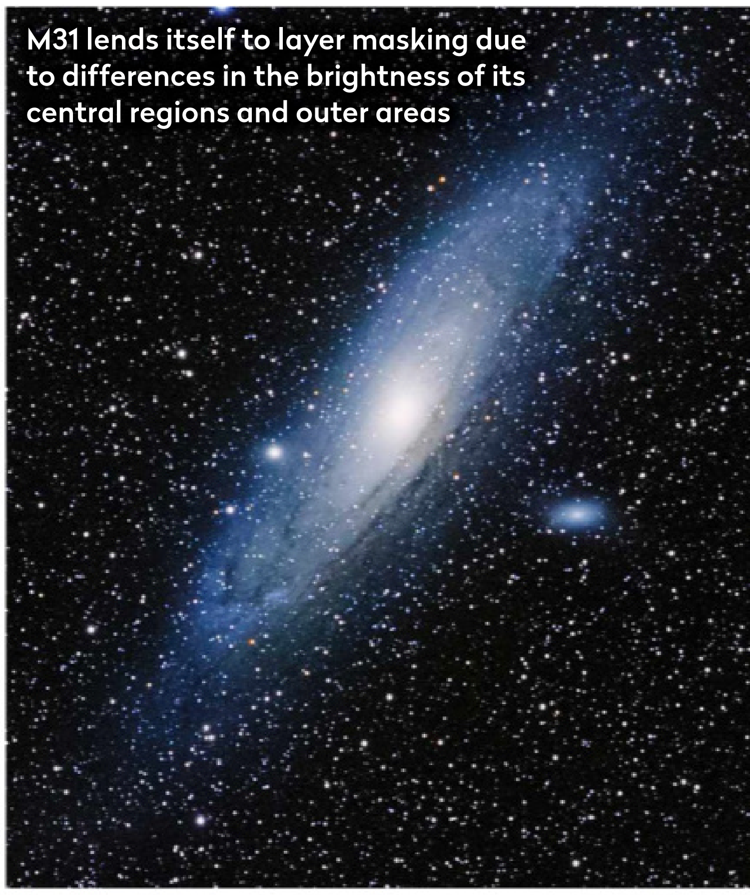
Using layers to deal with bright areas in deep-sky imaging

In this final case study we're going to bring together many of the techniques we've explored in the previous two step-by-step projects. In deep-sky imaging, having the ability to blend together two data sets, or two different images, in separate layers can be very useful when tackling some of the brighter targets.

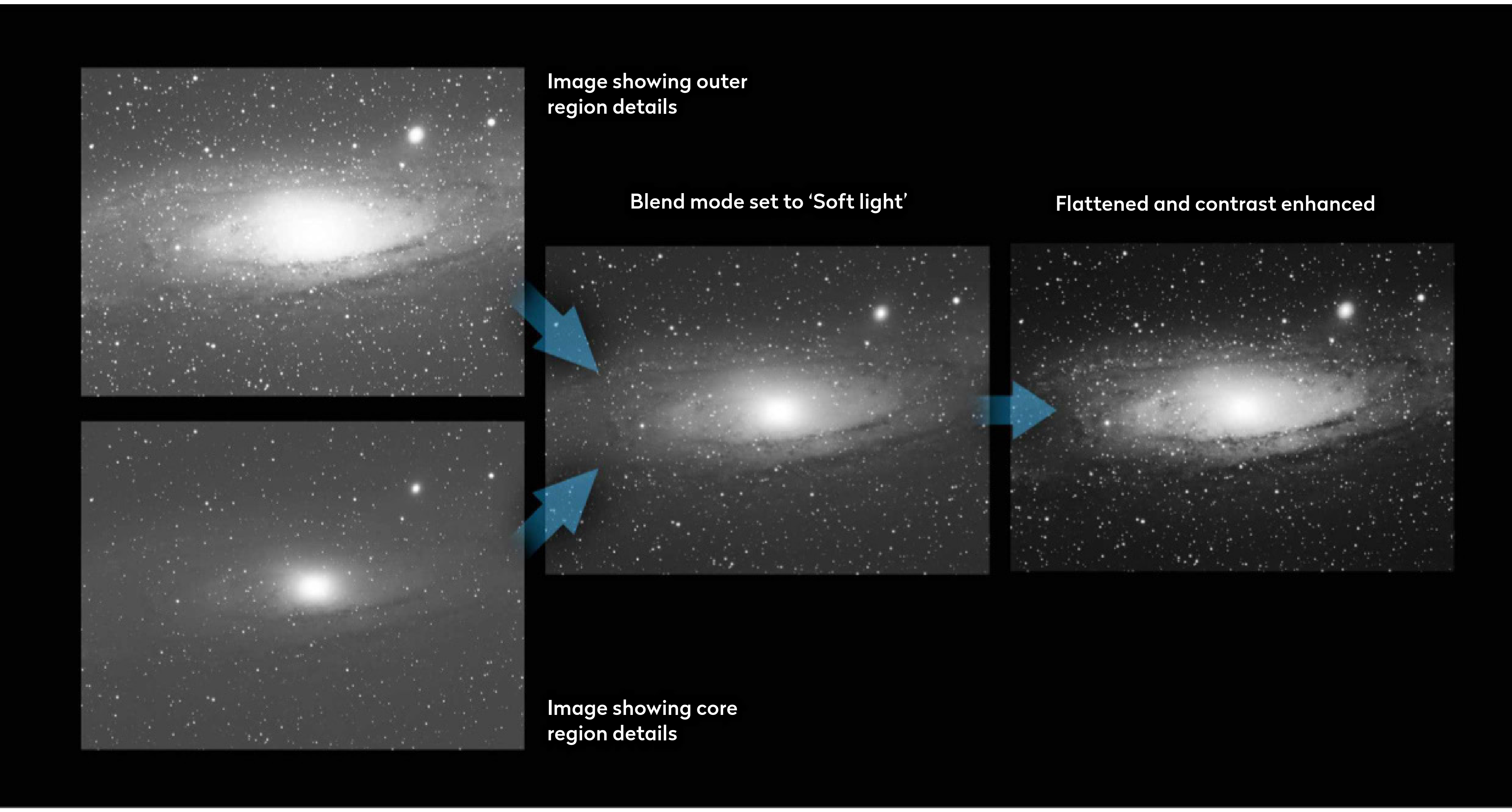
With objects like the Orion Nebula, M42, and the Andromeda Galaxy, M31, the core regions are quite bright compared to their surroundings. What this means is that if you set your exposure levels on your camera to pick up the faint detail in the outer regions of these targets, chances are the centre is going to be overexposed. Typically the way around this is to capture another set of shorter exposures of the central regions, then stack them separately; this data can then be blended with the other stack made from data exposed for the faint outer areas.

Let's imagine we're trying to combine the two images of the inner regions of M31 below. We've already seen how to bring two images into a layers-based editor and align them, and we could use a layer mask to then mask the overexposed core, allowing the data showing the central region to come through more clearly.

But there's another way to achieve a similar effect. That is to change the blending mode of the two layers. With the data showing the overexposed core in the upper layer, we could set its 'Blend Mode' (at the top of the layers window in both Photoshop and GIMP) from 'Normal' to 'Soft Light'. The result: a much better looking image, without the substantial blown-out core area, that can then be flattened down and processed to taste in numerous other ways.


M31 lends itself to layer masking due to differences in the brightness of its central regions and outer areas

Will Gater is an astronomy journalist and science presenter. His latest book, *The Mysteries of the Universe*, is published by DK



These images of M31 were taken with a monochrome camera and illustrate how a tweak to the 'blend mode' can bring together two layers

The fundamentals of astronomy for beginners

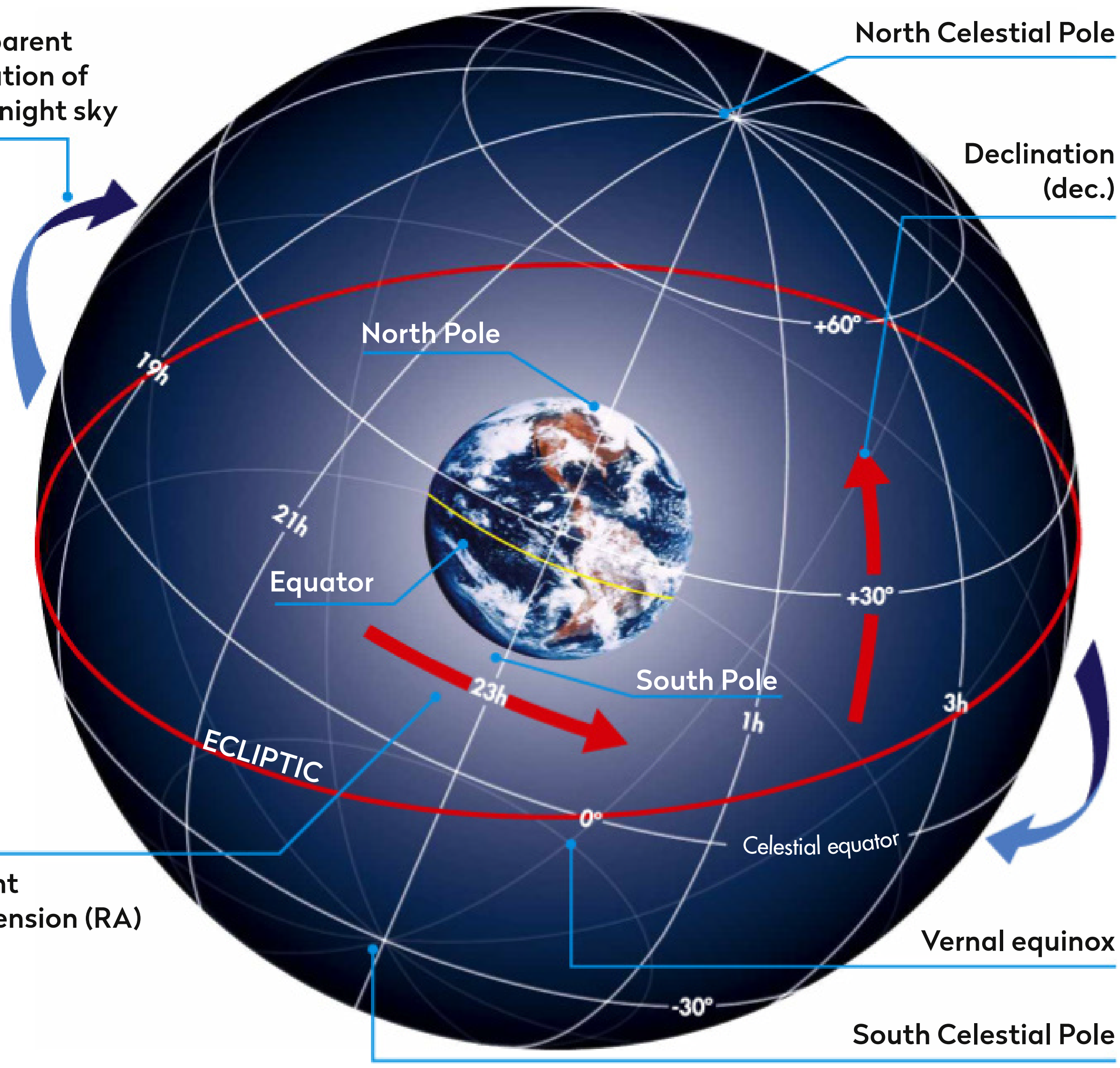
EXPLAINER

Get to know your way around the celestial sphere

Jane Green explains the system that helps astronomers to navigate around the heavens

The early Greeks believed that stars were embedded in an enormous sphere rotating around Earth. Today we know that stars and all the other celestial objects lie at varying distances, and they only appear to move from east to west as a result of Earth itself spinning on its axis from west to east. However, in order to describe the positions and movements of stars above our horizon, astronomers still use this vast imagined shell. It is called the celestial sphere.

Projected onto this sphere is a grid system of reference points and lines, which are similar to maps used on Earth. Imagine Earth as a balloon with reference points and lines mapped on its surface; inflate the balloon until it fills the celestial sphere and Earth's equator becomes the celestial equator, the celestial poles align with Earth's rotational north and south poles, and the lines of longitude and latitude become celestial coordinates – respectively right ascension (RA) and declination (dec.) – found on star charts and planetarium software apps, such as Stellarium or Star Tracker, used by stargazers around the world.



▲ The celestial sphere: Earth sits at the centre of the system, with the stars moving as if 'fixed' to the inside of a vast imagined shell

Mapping the sky

Declination in the night sky is mapped in the same way that latitude is measured on Earth: in degrees, arcminutes and arcseconds north and south of the celestial equator. Measurements increase from 0° on the equator to 90° at the poles. Declination north of the celestial equator is detailed as positive (+), while south is negative (–). As examples, Polaris (Alpha (α) Ursae Minoris), the pole star for the Northern Hemisphere, has a declination of just over +89° and Rigel (Beta (β) Orionis), the blue supergiant star marking the Hunter's foot in the constellation of Orion, is positioned at –8° 15 arcminutes below the celestial equator.

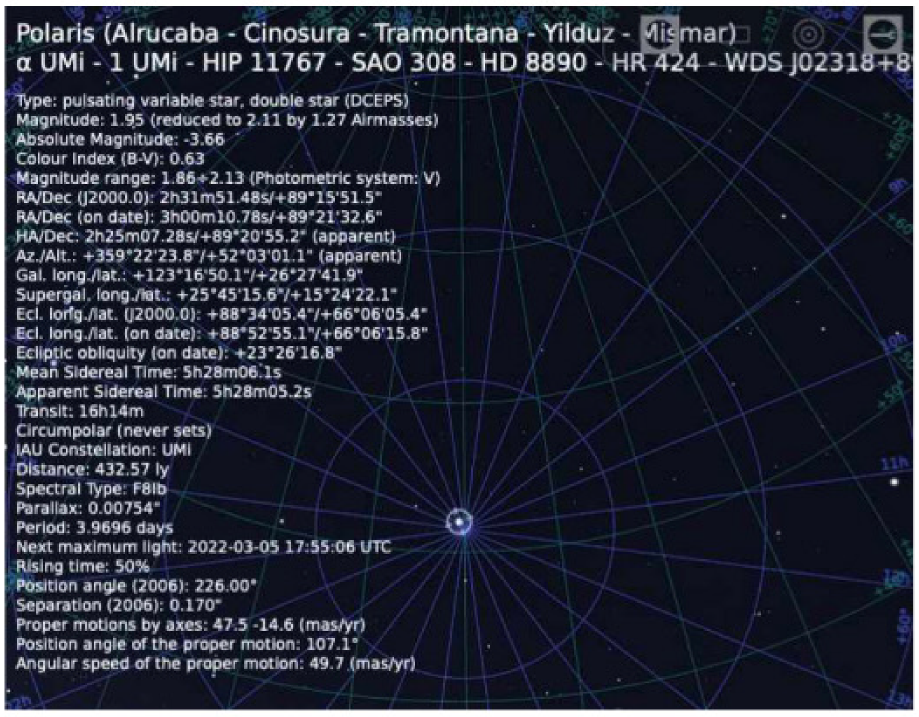
The celestial equivalent of Earth's longitude is called right ascension (RA) and although it can be shown in degrees, it is normally expressed in units of time: hours, minutes and seconds.

Twenty-four hours equals 360° and one hour of RA equals 15° of arc. The RA of the star Polaris is therefore described as 2 hours, 59 minutes and the RA of Rigel is 5 hours and 15 minutes. Every object in the heavens can be located by using these RA and dec. coordinates.

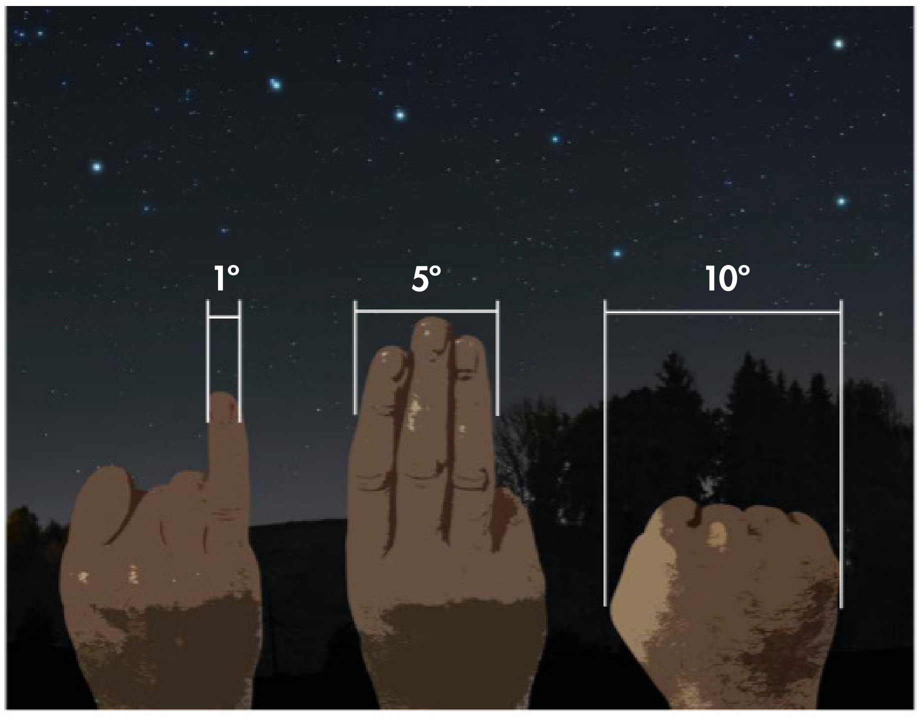
The zero (0) line of RA – the celestial equivalent of Earth's Greenwich Meridian of longitude – passes through the point where the Sun crosses the celestial equator at the first moment of spring in the Northern Hemisphere, the vernal equinox. Hours in RA are measured eastward from this point until 23 hours, 59 minutes is reached. One minute later and we return to 0 hours.

Dividing the celestial sphere is a line denoting the ecliptic, marking the apparent path of the Sun across the background stars – located by tracing a line between one or more planets and the Moon.

JANE GREEN/STELLARIUM, URSA MAJOR IMAGE: RASTAN/ISTOCK/GETTY IMAGES, PAUL WHITFIELD X 2



▲ **Planetarium apps like Stellarium are helpful for providing the celestial coordinates of targets like Polaris (Alpha (α) Ursae Minoris)**



▲ **Fingers are useful for measuring the apparent size of objects in the sky: the distances between them are measured in degrees**

Which stars can be seen and how they appear to move with respect to your location can be conceptualised using the celestial sphere. At the North Pole (90°), the North Celestial Pole corresponds with the zenith – the point directly overhead. The celestial equator is now parallel with the horizon and as stars move along a path parallel to the horizon, only those in the northern half of the celestial sphere are visible. At Earth's equator (0°) you can see all the stars since the celestial equator arcs from horizon to horizon via the zenith and the North and South Celestial Poles lie on the horizon. The stars rise straight up in the east and sink straight down in the west. Between these extremes, part of the sky always remains invisible. So if you're observing at either pole the stars will circle overhead and never set – they are circumpolar – but the stars circling the opposite celestial pole will remain invisible.

Your hands and fingers held at arm's length are ideal measuring tools for navigating the celestial sphere; an outstretched hand measures around 22° – the width of the Plough – and your little finger equals 1° – a full Moon's width.

Jane Green is an astronomy writer and author of the *Haynes Astronomy Manual*

Telescopes and star coordinates

How different mounts are used to guide telescopes using RA and dec. coordinates

Altaz mounts have two axes of rotation: one moves in elevation – up and down – 0° to 90° (altitude); and the other moves in a 360° circle parallel to the horizon (azimuth).

Equatorial mounts are like altaz mounts, but tilted at an angle based on the observer's longitude, which corresponds with Polaris's altitude. They compensate for Earth's rotation by having one rotational axis – the RA or 'polar' axis – parallel with Earth's axis of rotation. They are moved by manual adjustment using RA (right ascension) and dec. (declination) setting circles, or a small electric motor on the axes, within the RA and dec. coordinate system, which allows all-night tracking of objects on the celestial sphere.

Fully motorised and computerised **Go-To mounts** remove the need to know RA and dec. coordinates, as brighter objects are listed on a database accessed at the press of a button, but RA and dec. are still useful for locating fainter targets.

▲ **On an equatorial mount, adjust the declination (dec.) axis to move your telescope in a north–south direction...**

▲ **...and adjust the right ascension (RA) axis to move the telescope in an east–west direction**

Practical astronomy projects for every level of expertise

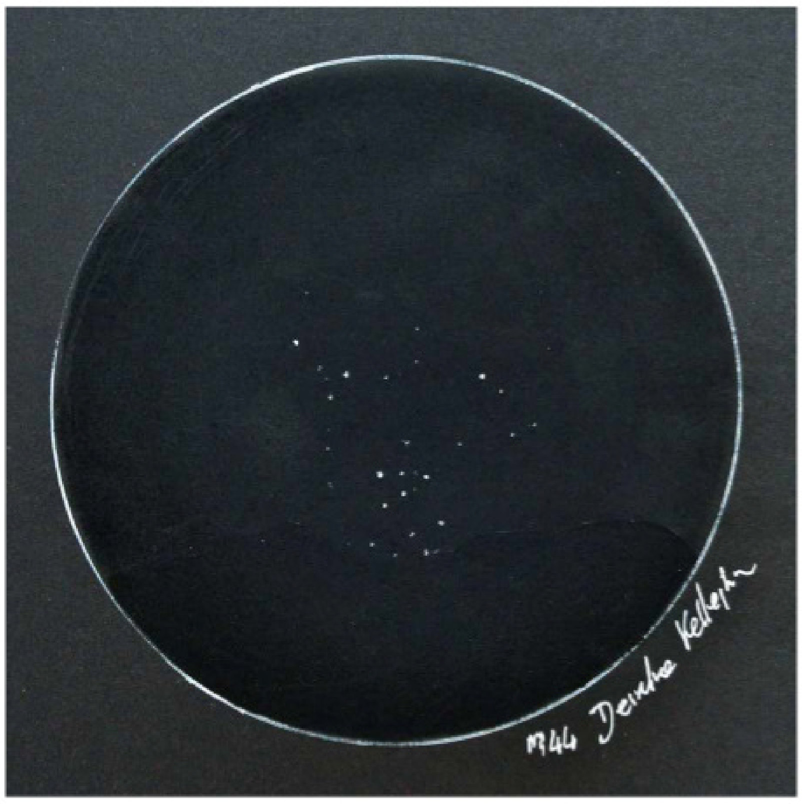
DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Sketch a deep-sky object at the eyepiece

Discover a simple and effective technique for recording your celestial observations

Viewing a deep-sky object for the first time can be a rewarding experience. Gazing at clusters that are located many lightyears away gives us a profound reminder of our place in the Universe. If you make the switch from observing to drawing, you'll find that what you draw becomes an authentic learning experience. In this article, I'll show you how to capture the Beehive Cluster, M44, and bring it down to Earth by drawing it. The process of making this happen can be a real pleasure, as you try and reproduce this deep-sky object as clearly and accurately as possible on paper.



▲ M44, as sketched over Killadoon Hill, Co Mayo, Ireland

Taking a new approach

When I began to draw deep-sky objects, the materials I found at my disposal were white paper and pencils. Although it was thrilling to look into nebulae and clusters with a pair of binoculars or a telescope, my initial efforts to record these targets were far from exact compared to what I saw. This wasn't because my efforts were inaccurate, but because space is black. Indeed, most of the observed objects were various tones of grey and white. I changed my approach to astronomical sketching, and using black paper was a real turning point. It opened up the possibility of using white gel pens for stars and soft pastels for nebulous material. You can experiment with different media and get familiar with how faint or bright each pen can be when you draw a star. The pen's size, plus how much you press on the paper, can be used to show different magnitudes.

To do an excellent job of any drawing requires motivation. When you look at open clusters with a massive amount of stars, it can be overwhelming at first, so you need to find an initial starter shape from which the rest of the drawing can grow.

On a cold wintry night, on 5 January, I noticed the Beehive Cluster was rising above a local hill, which provided an interesting aspect. M44 looked terrific against the top of the ridge, especially through my 15x70 binoculars. It provided an opportunity for making a sketch, which I did from 19:15–20:00 UT.

I began the sketch by drawing the hill's profile in pencil on my pre-prepared circle. Next, I spent a few minutes looking at the shapes made by the stars that were nearest the hill's edge. It was noticeable how fast M44 was moving upwards. I added brighter stars first, followed by dimmer ones.

There is a triangular shape at the heart of M44, which looks like '>' – the mathematical symbol for 'greater than' – through binoculars. With five bright stars and a few dimmer ones, this shape makes a good starting point for a drawing. Next I added fainter stars, such as those below the triangle, as it rose up from the hill, where there were two smaller triangles. These patterns are helpful as guides to build up a drawing and to add more detail. Make sure you always write on the drawing the start and end time, in Universal Time (UT), and the instrument used for the observation.

The drawing was finished indoors by painting black gesso over the hill area to separate it from the night sky. Spray fixative was used (outside with good ventilation) to seal the drawing, and the final sketch now provides a permanent reminder of this cluster.

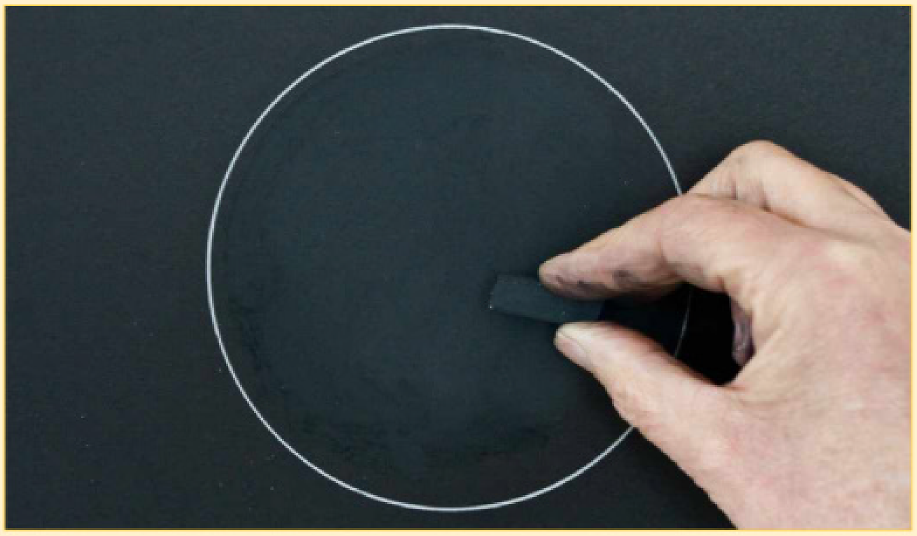
Deirdre Kelleghan is an artist, astronomer and educator

What you'll need

- Binoculars, 10x50s or larger on a tripod, or any telescope; if you are using a telescope, its lowest power eyepiece is best.
- A red headlight or a clip-on orange LED with a low setting; white gel pens with various size tips; colour gel pens.
- A clipboard and A4 black card or strong paper; black pastel; a spray fixative; warm clothing and a good sturdy seat are useful too.

ALL PICTURES: DEIRDRE KELLEGHAN

Step by step

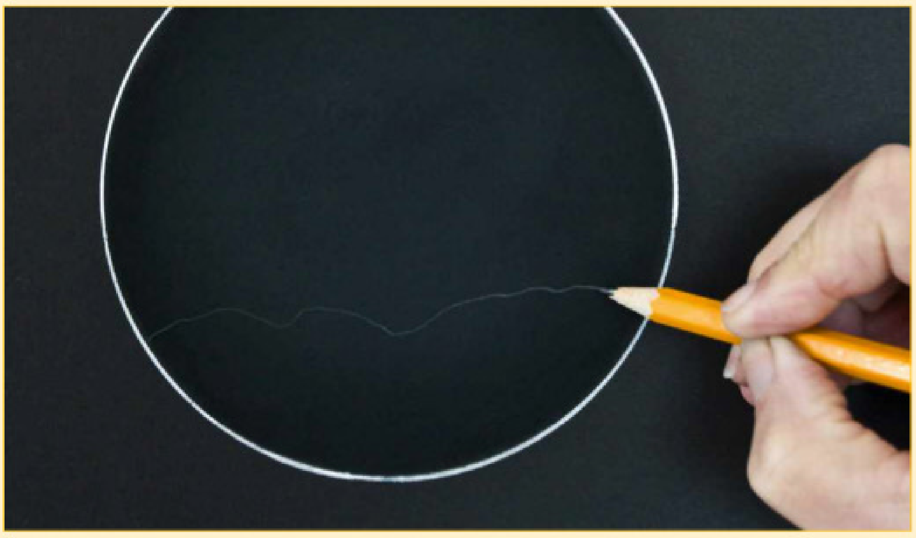


Step 1

Set up your binoculars on a tripod or telescope at a suitable safe and dark site. Have a sturdy seat, warm clothes and an illuminated clipboard to hand. Ideally, use a small fold-up table to place items such as the pens on for easy reach.

Step 2

Use a white gel pen to draw your circle with a CD or saucer. Using a soft black pastel, rub it in with your finger to fill the circle and blow off excess material. Try and have the circle as black as you can make it.



Step 3

Give yourself at least 20 minutes for dark adaption. If you are drawing M44 above an object, hill or house, use a pencil for those. Make it as accurate as you can and add other details to the hill after the main drawing is complete.

Step 4

Observe the patterns you see within the cluster. Decide for yourself which stars you can best place in the centre of your field of view and be mindful of how each star relates to each other. Always add bright stars first.

Step 5

Should you place a star incorrectly you can pick up black pastel on your finger and add it over the star you want to hide. Carefully re-introduce the star in its adjusted position. Add the remaining fainter stars that you can see as accurately as possible.

Step 6

The drawing was finished indoors by painting black gesso over the hill area to separate it from the night sky. Add the object's name, your name and any other details you wish to include, then use spray fixative (outside with ventilation) to seal the drawing.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Make a lunar eclipse animation

How to capture an entire lunar eclipse and create a flip-book style record from still frames

The total lunar eclipse on the morning of 16 May will be challenging: the the Moon will set around 05:00 BST (04:00 UT), just after the point of greatest eclipse and during morning twilight. The first part of the eclipse begins at 02:32 BST (01:32 UT) as the Moon moves into Earth's weak penumbral shadow, but this is hard to see visually. As the Moon progresses into the penumbral shadow, heading towards the outer edge of the umbral shadow, so the presence of the penumbra becomes more noticeable as a dark shading. The geometry of this eclipse means the line of approach towards the umbral shadow is optimised.

▲ **Aim to take photos of the Moon every 5–10 minutes during the eclipse**

Capturing the whole event

Our challenge this month is to record the entire eclipse from just before the penumbral insertion, in the form of an animation. For this to work, you'll need a photographic setup, which can record the Moon as a demonstrable disc. A 500mm-plus focal length will deliver this. Coupling your camera to a telescope with a focal length around the 1,000mm mark will be ideal.

Aim to take photos of the eclipse every 5–10 minutes over its duration. The brightening dawn twilight will need careful exposure adjustment to avoid overexposing the sky. This is important when totality arrives, as the Moon will be darker and the sky will brighten. Overexposing the dark umbral shadow brings out its colour at the expense of overexposing the penumbral eclipsed region.

Once the event has concluded, load each image into a layer-based editor, in time order, with the earliest image at the lowest level. Working up from the bottom of the stack, adjust the position of each lunar disc so that the high contrast features align. Next, it pays to check the edge space around each image in case the alignment process has brought the border of the image frame into view, creating a gap at the image frame's edge. If this is the case, fill in the gap. As a clean-up process, crop the image to chop off any excess bits, which may have become dragged off beyond the image border.

It's a good idea to save this image stack and keep it to one side, opening a copy of it for further work. In this way, if you do things to the image frames, for example by adjusting their brightness and contrast, and get it wrong you can always scrap the edit and go back. If the original stack has a large frame size, you may need to reduce this for animation purposes. A smaller frame will work well on a computer screen, produce a smaller, more transportable animation file and play in a smoother fashion. Keeping the large original safe will allow you to revisit it if the need arises.

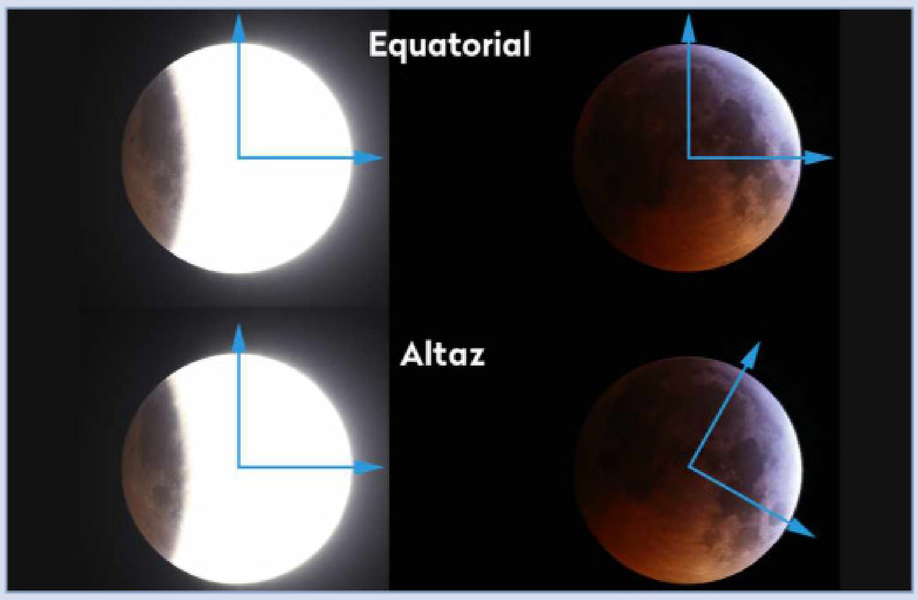
Once you've created the master frame stack, you can make a 'flick-book' animation. In our 'Step by Step' guide we look at using the freeware PIPP application (**bit.ly/3x2vCJ3**) for this task. If it works, you'll have an impressive animation to share with others.

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: a colour photographic camera (eg DSLR or MILC) with a 500mm or greater lens

Send your images to:
gallery@skyatnightmagazine.com

Step by step

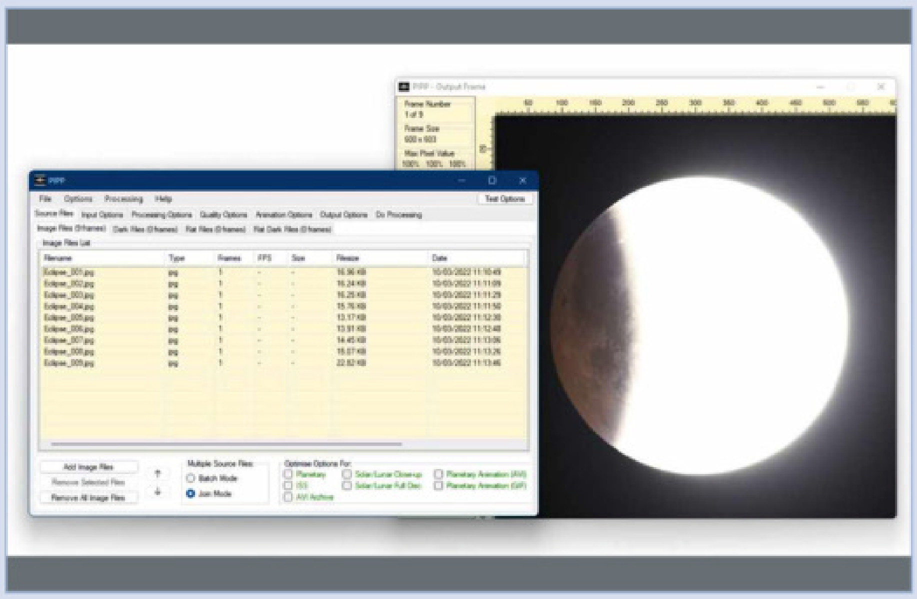


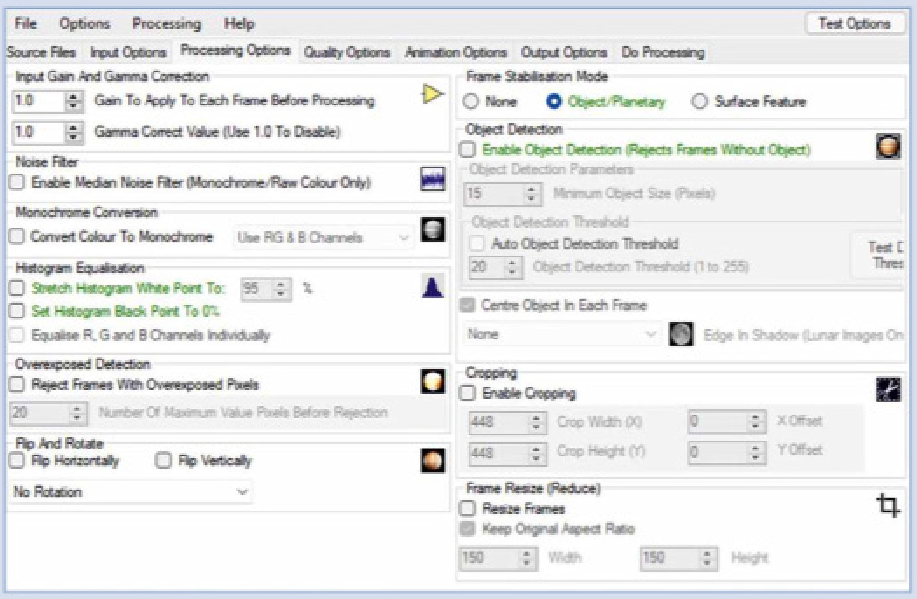
STEP 1

Take full lunar disc images at regular periods, of say 5-10 minutes from the start of the eclipse to moonset. An equatorial mount will remove frame rotation, which occurs when using an altaz setup. Camera adjustment is necessary as dawn breaks. Check the image histogram and avoid over-exposure of the sky.

STEP 2

When all your images are taken, download them to a computer. Open each shot and copy and paste as a separate layer into a master image, maintaining their time order in the layer stack. Next, align, tidy the edges and crop the final layer stack. Save the stack under a master file name, before working on a copy.



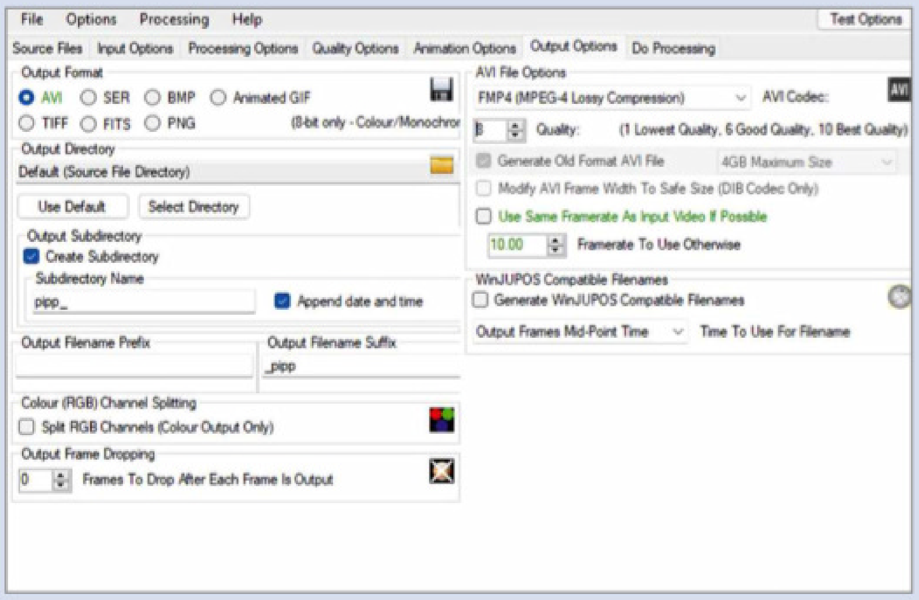


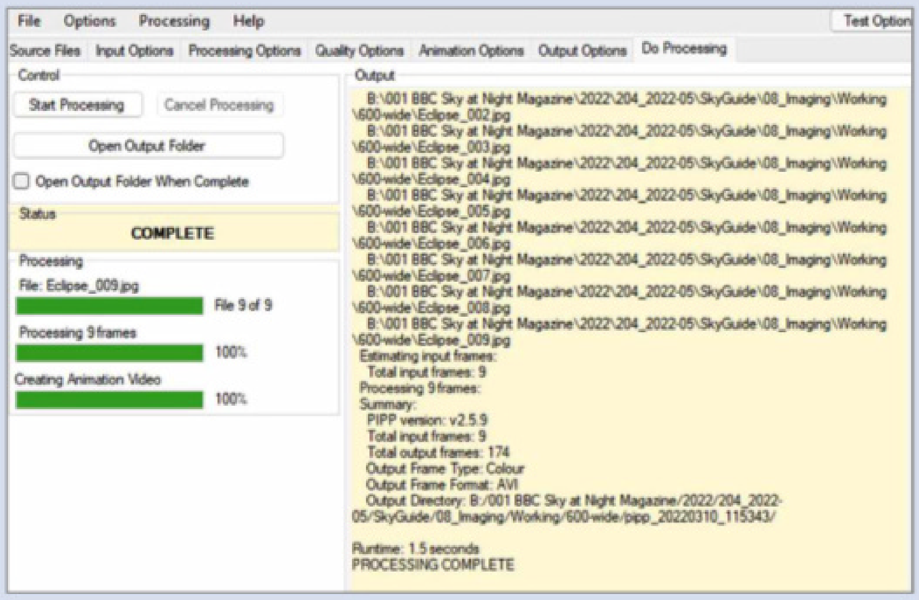
STEP 3

If you follow the main article you should end up with a number of eclipse images in a layer stack. Resize a copy of the master file to, say, 600 pixels-wide and save each layer as a sequence-numbered single image. Open PIPP and add all of the images into the 'Source Files' list. Dismiss the 'Join mode' message that pops up.

STEP 4

Ensure the frames are shown in the desired order, reflecting the sequence numbers given under Step 3 – 001, 002 etc. Make sure the 'Planetary Animation' option is ticked in the 'Optimise' panel. Under the 'Processing Options' tab, deselect all options. The alignment etc, will have been done building the layer stack.





STEP 5

The 'Animation Options' tab allows you to adjust the playback, so you can decide, for example, if you want to pause and reverse the sequence at the end. The 'Output Options' tab allows you to select the type of file to generate. We recommend AVI format with a 10 frames per second playback speed. Adjust 'Quality' to '8'.

STEP 6

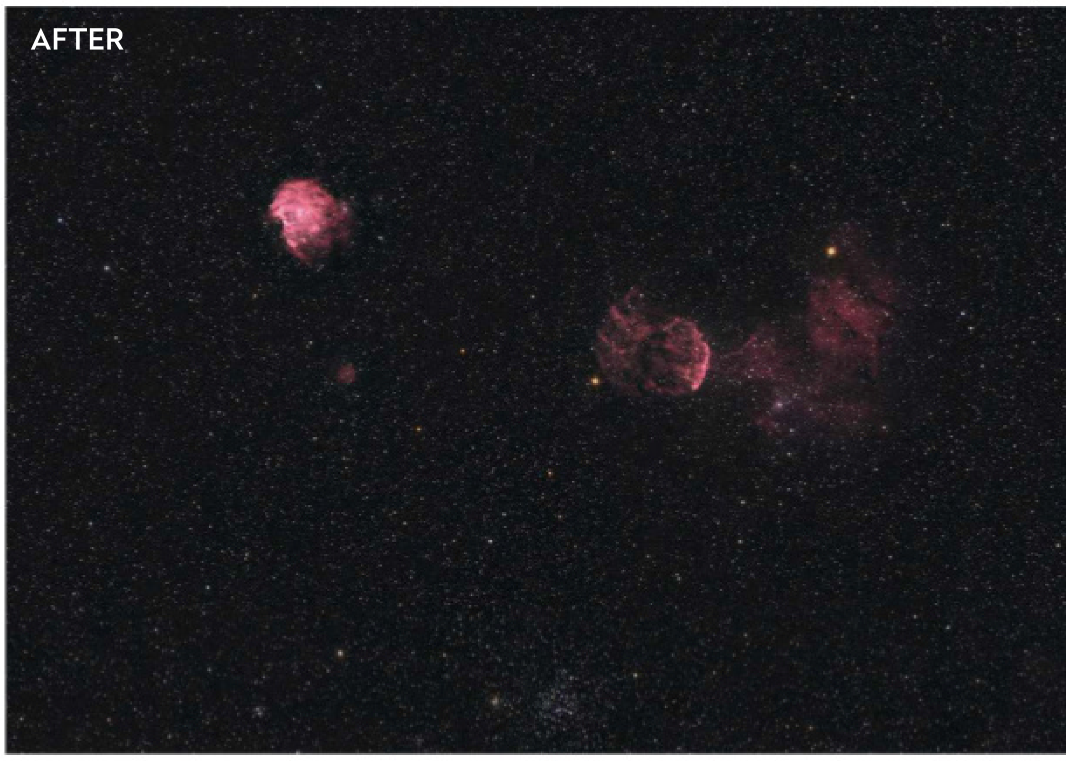
A final function tab is 'Do Processing', under which you click on 'Start Processing' to generate your animation file. The process is quick so you can easily go back and tweak the settings until the animation runs as you want. If the final animation is too large a file, try to reduce the size of the frames you are using.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Improving sky backgrounds in astro images

How a Photoshop plug-in can reduce light pollution and vignetting around a deep-sky target



▲ Left: The Jellyfish Nebula region, before the gradient control process has been applied

▲ Right: In the final image the background is more even and the vignetting has been removed

Astrophotography processing is about more than just stretching data and reducing noise, those unwanted artefacts. It is also important to create an even, realistic-looking background for your deep-sky objects. A flat, dark background will enhance the appearance of the target, but depending on the conditions you are imaging in, this can be a challenging thing to achieve.

Generally, you don't want to focus on making the background sky completely black, as this can look artificial. Thanks to light pollution and image-vignetting (where an image appears darker around the edges), captured images will often consist of uneven gradients – different patches of brightness or colour – that become more obvious as we stretch the data. These gradients can be difficult to correct evenly, which is where a software plug-in to help with gradient control can be particularly useful.

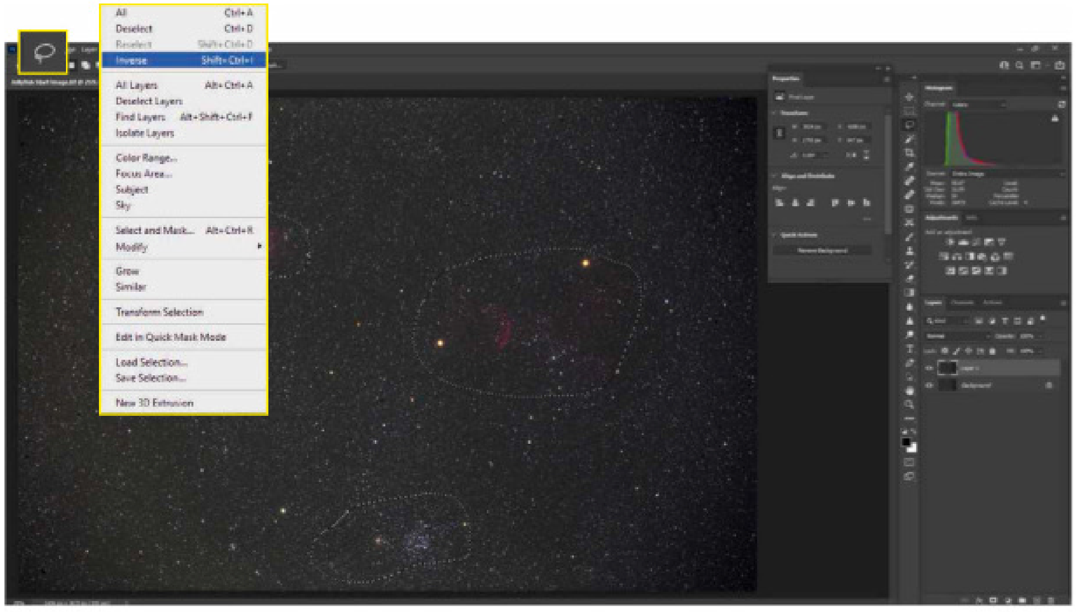
In Adobe Photoshop, gradient control can be carried out via basic functions such as 'Curves', but a Photoshop plug-in that can swiftly flatten gradients and restore an even background colour saves a lot of time. In this article we will show you how to use Russell Croman's useful GradientXTerminator Photoshop plug-in to adjust the gradients in a wide-field image of the Jellyfish Nebula, IC443. The plug-in is downloaded from his website, **bit.ly/3tsJNHr**, and a 30-day free trial is available before purchase. Once the plug-in is downloaded, you need to locate it – for Windows computers it is found in the 'C:/drive › Downloads'.

The file needs to be transferred to your Photoshop plug-ins directory, the location of which depends on the version of the software you are using. For Photoshop 2022 on a Windows computer, click and drag the file to 'C:\Program Files\Common Files\Adobe\Plug-Ins\CC'.

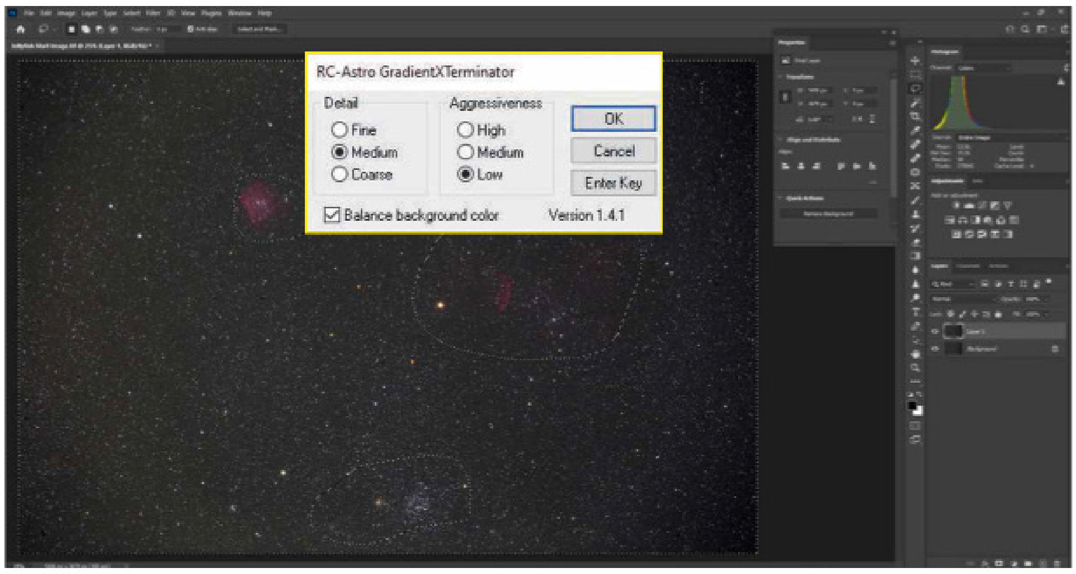
Stand-out nebule

It's best to apply GradientXTerminator after a 'stretch' of the data using the 'Levels' function (click 'Image › Levels'), as we've done in our 'Before' image (see above, left). So in the 'Levels' window, drag the anchor points closer in towards the histogram, allowing it to widen and details to emerge. Although this step was repeated several times to

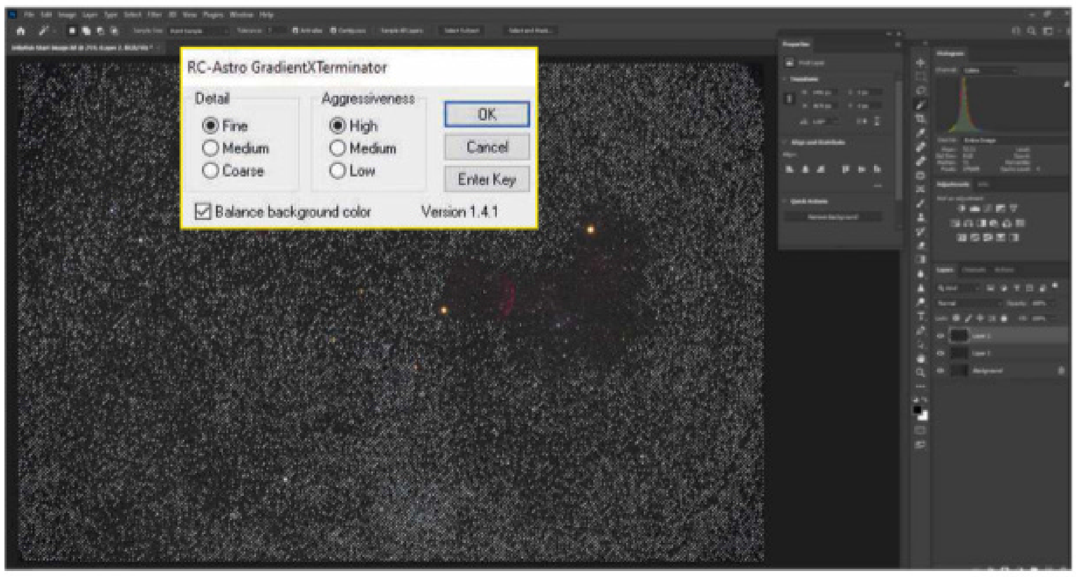
ALL PICTURES: CHARLOTTE DANIELS



▲ **Screenshot 1: Prepare the regions that you want the plug-in to ignore by using Photoshop's 'Lasso' tool and the 'Select › Inverse' function**



▲ **Screenshot 2: Apply a 'Medium' gradient adjustment to the background sky using the GradientXTerminator plug-in**



▲ **Screenshot 3: With GradientXTerminator selected, use the 'Tolerance' levels in the top menu to make a finer gradient adjustment to the background**

make the nebulae stand out in our 'Before' image, there is still a vignette disrupting the image, so it's now time to remove these gradients.

Before you use the Gradient XTerminator plug-in, remember that you only want to apply it to the background, rather than the target. If you allow the plug-in to change the target appearance too, it can remove some colour or nebulous detail. To avoid this happening, use the 'Lasso' tool in Photoshop: select the icon from the Toolbar on the left-hand side of the screen and then drag the 'Lasso' tool around the

3 QUICK TIPS

1. The best 'Tolerance' settings depend on the deep-sky object – ensure dusty details are not highlighted.

2. Apply GradientXTerminator in stages: use the 'eye' icon for that layer to view each change.

3. For Magic Wand, the 'Alt' key allows you to add or subtract regions. A plus or minus will appear next to the icon.

objects. Although this action automatically 'selects' regions within the 'Lasso', you want to 'deselect' these regions to ensure GradientXTerminator ignores them. To do this click 'Select › Inverse' to focus on the regions outside the 'Lasso' (see Screenshot 1).

Now it's time to apply the plug-in, which is accessed via the 'Filters' menu, by clicking 'Filters › RC Astro › GradientXTerminator'. For the first gradient adjustment, in the plug-in window, select 'Detail › Medium' and 'Aggressiveness › Low' (see Screenshot 2). Although this applies a broad correction to the background, some gradients are still present.

To make a finer adjustment to complete the gradient removal, without the risk of over-flattening our background, select the 'Magic Wand' tool from Photoshop's Toolbar. A menu appears on the top of the screen, allowing you to set the strength. Set the 'Tolerance' to '7' on this occasion, but the best value will depend on the image. Generally, the best value will range between '5' and '10'.

Background checks

Now click on an area in the background, which depending on the 'Tolerance' setting chosen should select most of, or all of the background (but not the object). It is important to ensure the target is left untouched by GradientXTerminator, so this process takes a little trial and error. Make sure you experiment with the 'Tolerance' setting until you have most of the background selected minus the target(s) of your image.

Then click on GradientXTerminator again, and this time set the 'Detail' to 'Fine', and the 'Aggressiveness' to 'High' (see Screenshot 3). This will ensure finer gradients are dealt with, giving a smoother result. In the 'After ' image, the background now looks more even, with colour gradients and vignetting removed. All that is left is to make some final Photoshop adjustments by using 'Selective Color' and 'Brightness' (click 'Image › Adjustments') and 'Dust and Scratches' ('Filters › Noise'), before saving it.

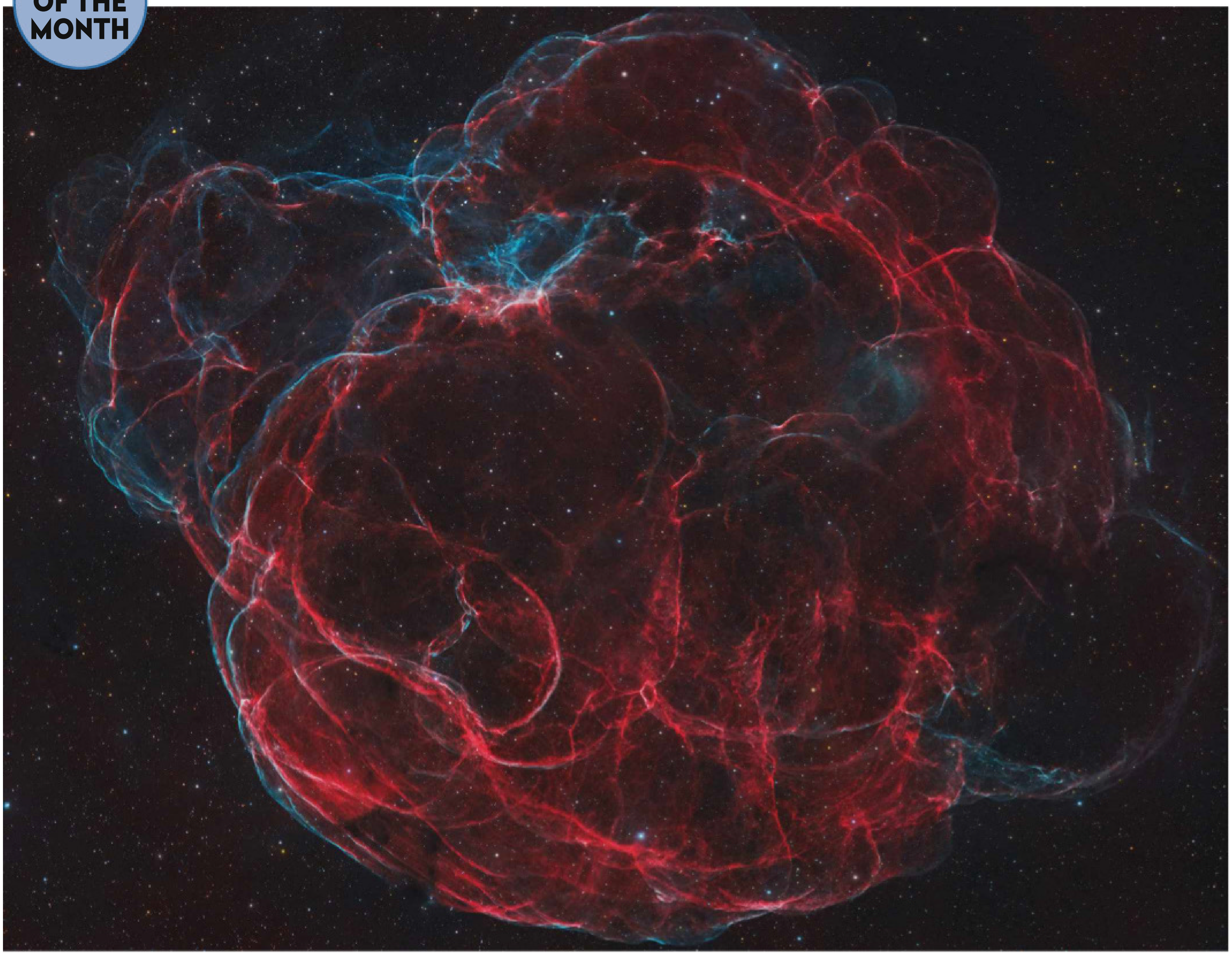
Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More ONLINE
A gallery containing these and more of your images

PHOTO OF THE MONTH



△ The Spaghetti Nebula, Simeis 147

Yann Sainty, France, 11 October 2021–1 March 2022

Yann says: "The Spaghetti Nebula is an object that I'd always dreamed of shooting, but I knew it wouldn't be easy. I decided to put all the chances on my side by travelling to shoot where the weather would allow it: from the Vosges mountains to Alsace (camping in 0˚C) and Moselle in the east, down to Valensole and several other locations in the south. It took me two months and a total of 3,600km to acquire 55 hours of data for a final two-panel mosaic of 15,000 x 12,000 pixels."

Equipment: ZWO ASI2600MM Pro camera, Takahashi FSQ-106ED refractor, Sky-Watcher ER6-R Pro mount **Exposure:** Panel 1: Ha 71x 600", OIII 78x 600", RGB 90x 10" each; Panel 2: Ha 94x 600", OIII 78x 600", RGB 90x 10" each **Software:** Siril, PixInsight, Photoshop

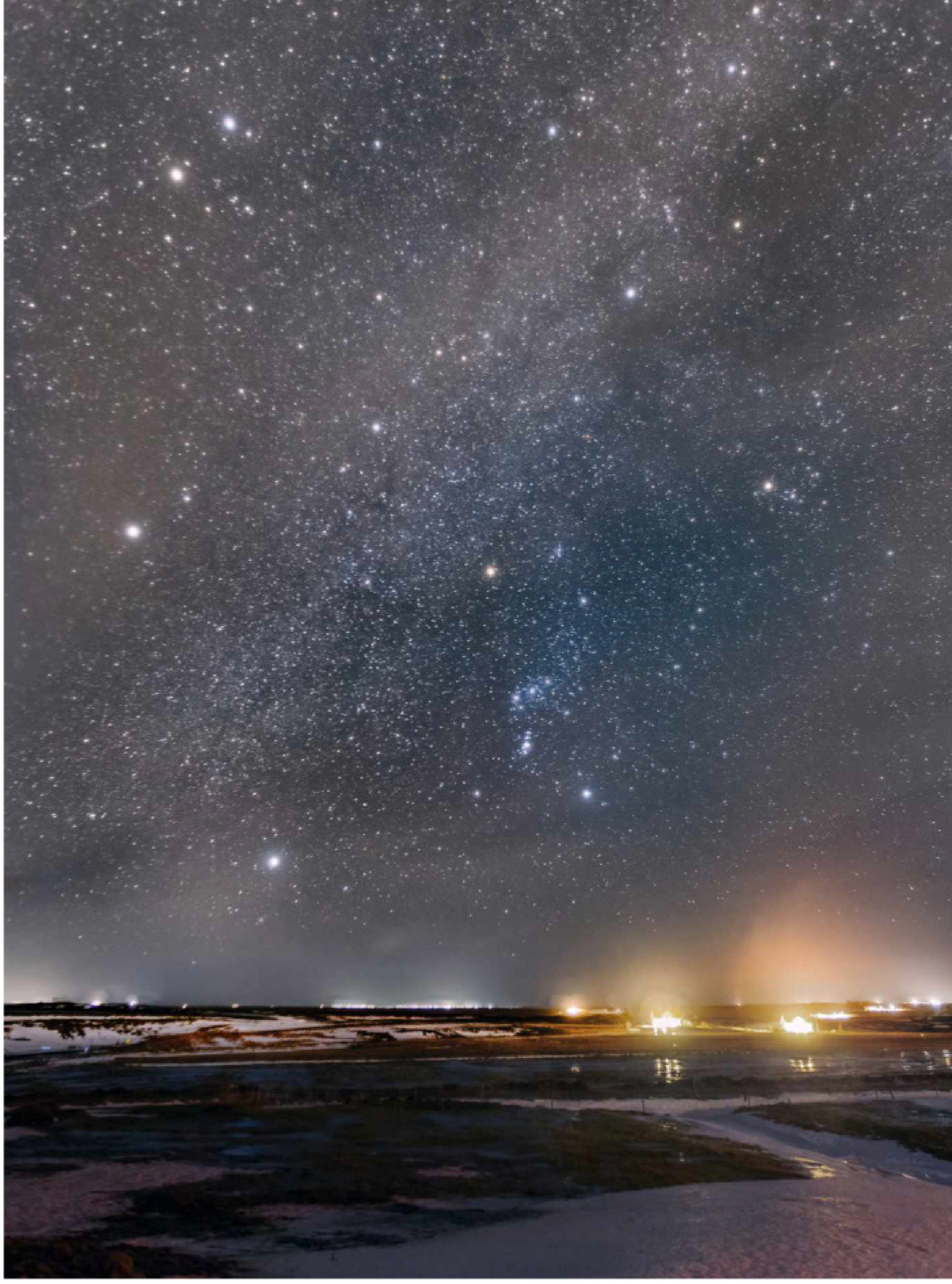
Yann's top tips: "For a big, faint supernova remnant, a good monochrome camera like the ASI2600MM – with high quality filters, like the Antlia 3nm – is key, plus a fast focal length scope. I recommend at least 600" sub frames to catch as much light as possible. Take time with processing: I processed the object without stars and added them afterwards. A two-panel mosaic demands more time, but the results are worth it."

△ Solar activity

John Chumack, Dayton, Ohio, USA, 5 March 2022

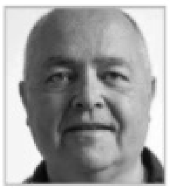
John says: "It's so nice to see the Sun with so much activity again, with at least four active regions, several filaments, bright plages, sunspot groups and plenty of prominence activity all around the limb."

Equipment: QHY5L-II CMOS camera, Lunt LS60 solar telescope with B1200 filter, Bisque MYT mount **Exposure:** 4.2ms, 495 frames stacked **Software:** RegiStax



△ Winter Circle

Chris Platkiw, Hella, Iceland, 3 March 2022



Chris says: "I waited in –6°C wind chill for the clouds to clear and grabbed this view of the winter constellations."

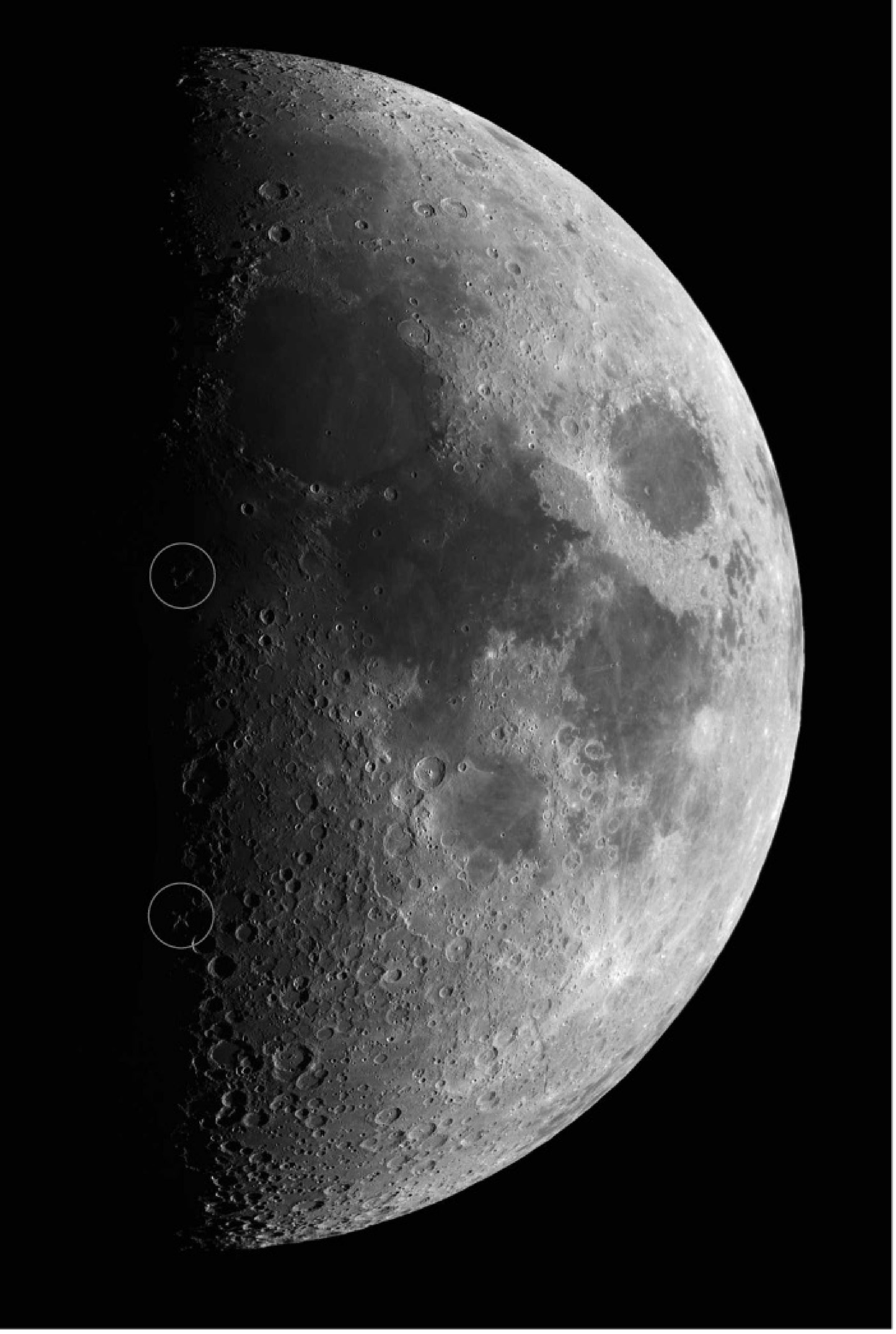
Equipment: Canon EOS R mirrorless camera, Canon 17–35mm lens, Benro A0685F tripod **Exposure:** ISO 6400 f/3.2, 30x 15" **Software:** Starry Landscape Stacker, PixInsight, Photoshop

◁ Arp 271

Warren Keller and Mike Selby, El Sauce Observatory, Rio Hurtado, Chile, 3 June 2021

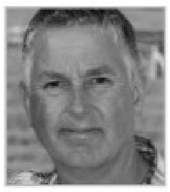
Warren says: "MaxIm DL's deconvolution filter helped to pull out the fine detail from this beautiful pair."

Equipment: FLI ProLine PL 16803 camera, PlaneWave PW1000 Nasmyth astrograph **Exposure:** L 17h, RGB 6h each **Software:** PixInsight, Photoshop, MaxIm DL



◁ Lunar X and V

Jamie Cooper, Whilton, Northants, 8 February 2022



Jamie says: "Here's an eight-pane mosaic showing the first quarter Moon with the Lunar X and V visible along the terminator."

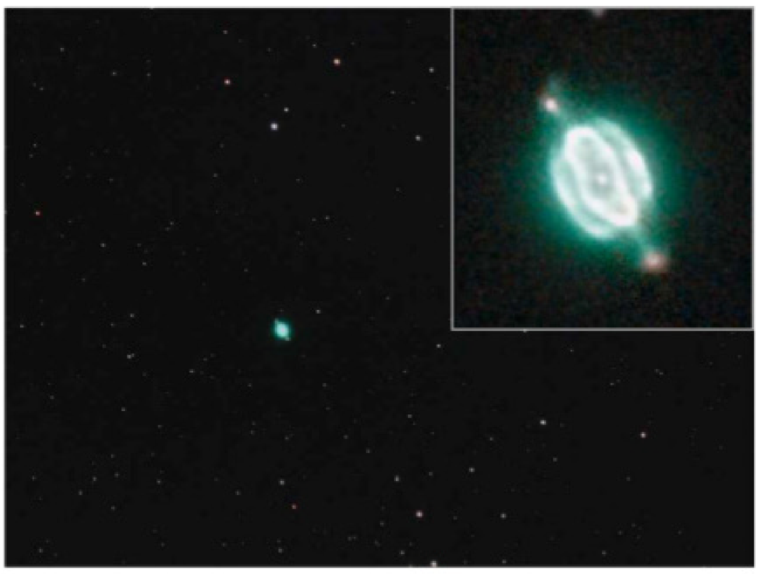
Equipment: ZWO ASI290MM camera, Sky-Watcher 250PDS Newtonian reflector, EQ6 mount **Exposure:** 80fps, 4,000 frames, best 100 stacked **Software:** AutoStakkert!, RegiStax, Photoshop

▽ The Saturn Nebula, NGC 7009

Fernando Oliveira de Menezes, Jales, São Paulo, Brazil, 7 October 2021

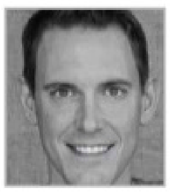
Fernando says: "I've combined a wide-field and a close-up view of this nebula that's shaped like our favourite ringed planet."

Equipment: ZWO ASI6200MC camera, Sky-Watcher 150ED refractor, CEM60 mount **Exposure:** 64x 50" **Software:** SGPro, PixInsight, Photoshop



The Cone Nebula/ Christmas Tree Cluster ▷

Jeffrey Horne, Nashville, Tennessee, USA, 26 November 2021–19 February 2022



Jeffrey says: "I hadn't planned on spending over 100 hours on this image, but as I kept piling on data, more and more detail appeared."

Equipment: ZWO ASI2600MC Pro camera, TPO UltraWide 180 refractor, Sky-Watcher EQ6-R Pro mount **Exposure:** Stars 350x 5", narrowband 759x 480" **Software:** APP, PixInsight, Photoshop

NGC 6744 ▷

Basudeb Chakrabarti, via Telescope Live, El Sauce Observatory, Chile, 29 November, 5 and 6 December 2021

Basudeb says: I'm always fascinated by the sheer beauty of galaxies. NGC 6744 was quite a difficult target when it came to post processing."

Equipment: FLI ProLine PL9000 camera, Planewave CDK24 astrograph, Mathis MI-1000 mount **Exposure:** 16h 50' total **Software:** DeepSkyStacker, PixInsight, Photoshop

◁ The Rosette Nebula

Rachael and Jonathan Wood, Doncaster, 3–6 January 2022

Rachael says: "This image was produced using a fake Hubble palette, as this target really reveals its different layers when you can see the range of gas and colour within."

Equipment: ZWO ASI294MC Pro camera, Sky-Watcher Evostar ED80 refractor, Sky-Watcher EQ5 Pro mount **Exposure:** 8h total **Software:** APP, Photoshop

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hama.

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a Hama Lens Pen, designed for quick and easy cleaning of telescope optics, eyepieces and camera lenses. It features a retractable brush and non-liquid cleaning element. **www.modernastronomy.com • 020 8763 9953**

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86 Discover how well the Starbase 80 refractor and mount system measures up for deep-sky observing

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HOW WE RATE

Each product we review is rated for performance in five categories.
Here's what the ratings mean:

★★★★★ Outstanding ★★★★ Very good
★★★ Good ★★ Average ★ Poor/avoid

PLUS: Books about the cosmos for children and imaging the Solar System, and a roundup of the latest gear

Starbase 80 refractor and mount package

A user-friendly system with an achromatic telescope and portable altaz mount

WORDS: PAUL MONEY

VITAL STATS

- **Price** £605
- **Optics** 80mm
- **Focal length** 800mm (f/10) focal length
- **Mount** Altaz mount with adjustable steel tripod
- **Focuser** Rack and pinion
- **Extras** Peep hole finder, 6mm & 14mm 1.25 inch-fit eyepieces, smooth slow-motion control cables, star diagonal and accessories tray
- **Weight** 6kg
- **Supplier** First Light Optics
- **Email** questions @firstlight optics.com
- **www.**firstlight optics.com

The Starbase 80 refractor and mount package from First Light Optics is manufactured on behalf of Takahashi in Japan. Although it is not actually made by Takahashi, the livery of the Starbase 80 is reminiscent of the pale green and white often associated with that company. The aim is to provide an entry level, grab and go achromatic telescope on a portable easy-to-use altaz mount, which will complement the usual high-quality Takahashi optical systems we are used to seeing.

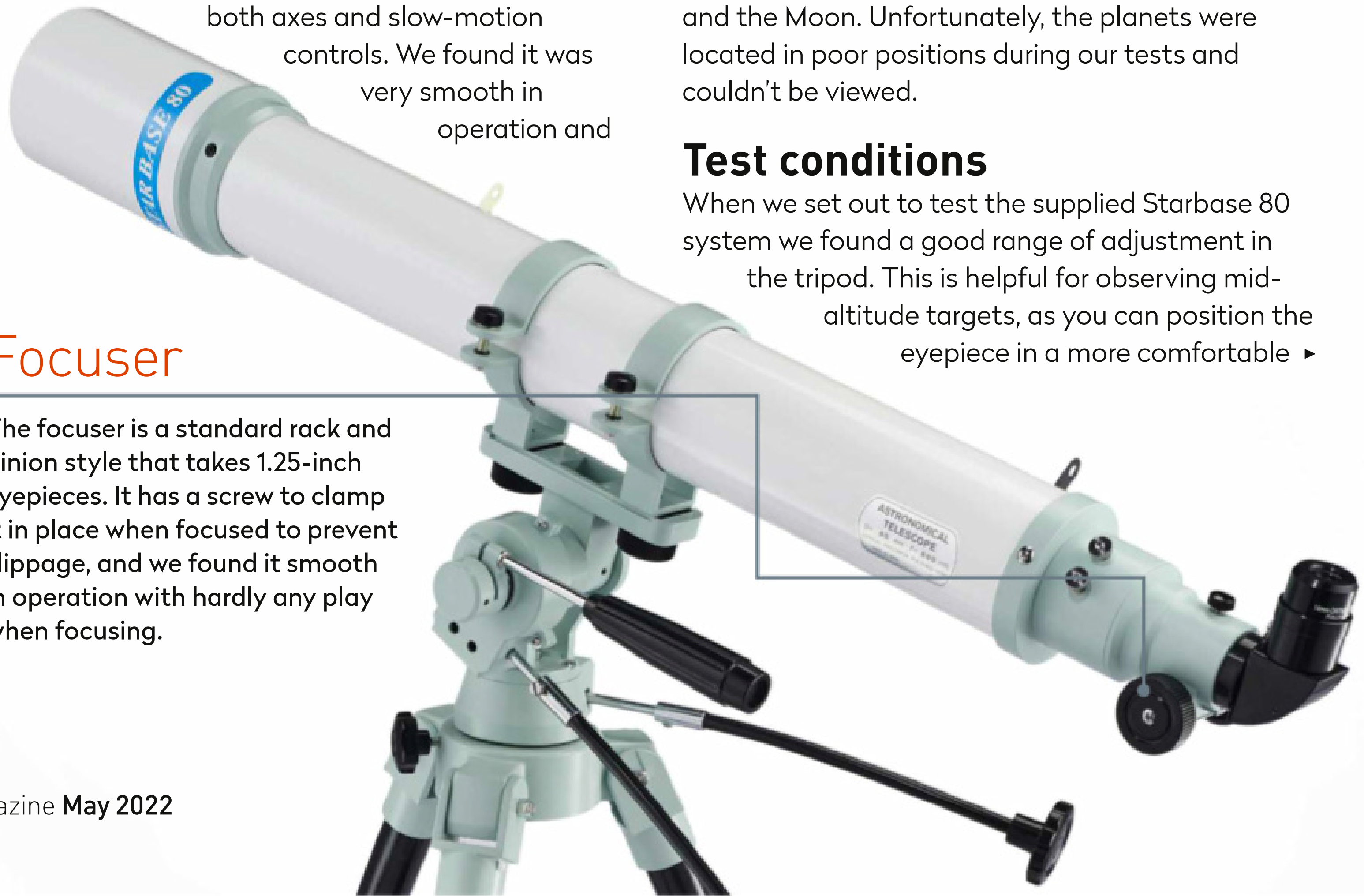
The assembly of the Starbase 80 system proved to be straightforward, with the mount and tripod in one section, so all we needed to do was to attach the tube and rings to it, before adding the slow-motion controls and altitude clamp. Next, we added the star diagonal and an eyepiece and we were ready to go.

The objective lens, a fully magenta-coated achromat, is 80mm in diameter with a focal length of 800mm, which gives a focal ratio of f/10. The mount is an altaz design with clamps for both axes and slow-motion controls. We found it was very smooth in operation and the design also allowed us to view high-altitude targets, although it does put the eyepiece in a position that's quite low down to reach. There was little in the way of play on both axes so we could be confident that a target would stay in the field of view when we fine-tuned its position in the eyepiece.

Normally, we would expect to see a finderscope in a basic package like this, but the Starbase 80 employs a peep hole finder system. Imagine two small right-angle pieces of Meccano attached to the optical tube: you line them up and look through them. This works well for bright stars, but it's a little harder when you are trying to home in on deep sky targets. Two Orthoscopic 1.25-inch eyepieces are supplied in the standard package along with a star diagonal. Interestingly, these eyepieces are not the regular 25mm and 10mm types that basic systems are often supplied with. Instead, we have 14mm and 6mm eyepieces, which give magnifications of 57x and 133x respectively. Although this did seem an odd combination, they worked quite well in use, allowing us to view a wide range of deep-sky targets and the Moon. Unfortunately, the planets were located in poor positions during our tests and couldn't be viewed.

Test conditions

When we set out to test the supplied Starbase 80 system we found a good range of adjustment in the tripod. This is helpful for observing mid-altitude targets, as you can position the eyepiece in a more comfortable ►



ALL PHOTOS: @THESHED/PHOTOSTUDIO

Focuser

The focuser is a standard rack and pinion style that takes 1.25-inch eyepieces. It has a screw to clamp it in place when focused to prevent slippage, and we found it smooth in operation with hardly any play when focusing.

Optics

The 80mm (3.2-inch) objective lens is a fully magenta coated achromatic to help improve contrast. It has a focal length of 800mm, which gives the system a focal ratio of f/10. The tube is lightweight and fitted with pale green tube rings for attaching to the mount.

Tripod

The steel tripod is lightweight, yet sturdy enough to support the mount and telescope. It has adjustable legs to make the viewing height more comfortable, and it has a simple but useful plastic accessories tray that also helps to spread the tripod legs and keep them in position.

SCALE

Sturdy altaz mount

One of the weak points in cheap, basic telescope packages is often the mount, which can prove to be sloppy and quite loose in operation, but this isn't the case with the Starbase 80. Plenty of thought has gone into making this altaz mount one that is rigid and sturdy, which provides good support to the telescope. The altitude clamp allows enough friction to move the telescope up and down smoothly before locking into place, so you can fine-tune the altitude with the slow-motion control. There is also a useful altitude scale on one side to help you aim the telescope.

Similarly, the azimuth clamp works just as well, allowing a full 360° rotation before clamping, then fine tuning with its slow-motion control. However, we would like to have seen an azimuth scale on this axis. The design of the mount also ensures that any targets that are high in altitude can be reached without the telescope striking one of the tripod legs. However, it does place the eyepiece at a very low position, so plan your targets carefully.

Accessories

The supplied Starbase 14mm and 6mm Orthoscopic eyepieces, with 57x and 133x magnifications, provided us with good views of our selected targets. The star diagonal uses a prism and allows you to look into the telescope at right angles instead of having to strain your neck by looking up through the tube.

Peep hole finder

The finder is unusual in that it is a peep hole-style system with two holes that you line up and look through. It works reasonably well for bright stars if you have good eyesight, but can be a little awkward if you are aiming the telescope high into the sky.

▸ The Moon, as captured afocally using the Starbase 80 refractor with an iPhone 13 Pro Max held to the 14mm eyepiece

▸ position when using a seat. Not only were we able to find the brightest deep-sky targets like the Orion Nebula, M42, and the Pleiades, M45, but we were able to locate the hazy central bulge of the Andromeda Galaxy and several bright double stars too. With the 14mm eyepiece, we found that the Pleiades star cluster more than filled the view, while the Orion Nebula was enjoyable, with a good deal of visible nebulosity along with the four bright Trapezium Cluster stars at the centre.

Double benefits

Just south of the Orion Nebula is the double star Iota (ι) Orionis, which was nicely split, so we moved up to try Sigma (ς) Orionis and we could see the main three stars and the fainter fourth with averted vision. Upping the magnification with the 6mm eyepiece, we could split Castor (Alpha (α) Geminorum) in the constellation of Gemini, the Twins, and Algieba (Gamma (γ) Leonis) in Leo, the Lion. We noticed a faint reddish halo, which is often the case with achromatic systems because they don't quite bring all the spectrum to a focus point, but it wasn't too distracting. Next, we turned our attention to the Moon, which was crisp in both the 14mm and 6mm eyepieces. We were very pleased to discover that these revealed lots of detail, in and around the craters that were close to the terminator, which will no doubt provide plenty of hours of viewing pleasure.

There are optional extras, such as the Starbase 6x30 finderscope and 20mm and 9mm eyepieces, which we were loaned for the review. Adding the 6x30 finderscope boosted our success in finding fainter targets such as the spiral galaxy NGC 2903 in Leo, the Lion, and the open cluster M41 (sometimes known as the Little Beehive Cluster) in Canis Major, the Greater Dog. The 20mm eyepiece allowed us to fit all the Pleiades, M45, in the field of view, which was very satisfying. Meanwhile, the 9mm eyepiece gave us a crisper view of our selected double stars, without pushing the magnification too far, so again we would consider adding these as upgrades to the system.

Overall, this grab and go Starbase 80 system will provide an excellent entry-level opportunity for amateur astronomers, with a good variety of targets on view.

VERDICT

Assembly	★★★★☆
Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★½☆
Optics	★★★½☆
OVERALL	★★★★☆

KIT TO ADD

1. Starbase 6x30 Finderscope

2. Starbase 9mm and 20mm 1.25-inch Orthoscopic Eyepieces

3. Universal smartphone adaptor

@THESHED/PHOTOSTUDIO X 4, PAUL MONEY

Our experts review the latest kit

6 OF THE BEST

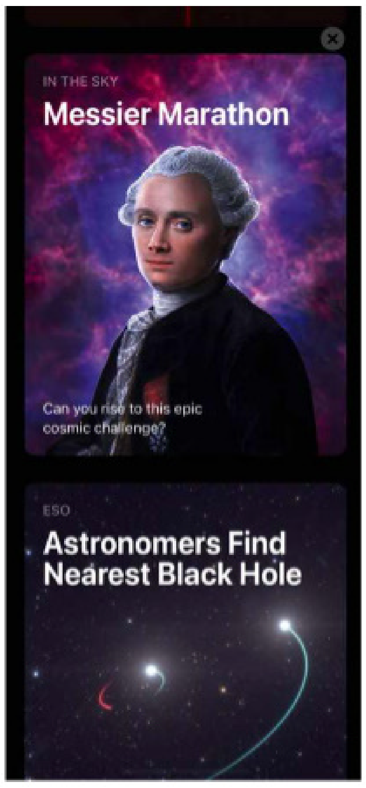
iPhone planetarium apps

Apple stargazing apps come with many features, so which one is best for you?

WORDS: JAMIE CARTER

Sky Guide

Price Free; All Constellations art & stories £1.79; Plus £17.99 per year, Pro £34.99 per year • **OS minimum version requirement** iOS 14.0 • **Developer** Fifth Star Labs • **www.**fifthstarlabs.com • **https:**//apps.apple.com/gb/app/sky-guide/id576588894



The latest iteration of the Sky Guide app, Version X, sees upgraded visualisations and lots of great background astronomy news. The night sky has more realism than ever, including beautifully rendered pre-dawn light, twilight and dusk, as it takes on a more accurate, practical look than before.

We're not quite sure, however, how useful it is to point a smartphone at the daytime sky and only get information for the Sun (though you can toggle on and off the 'stars fade during day' option). Ditto for some fine but fanciful aurora effects, which can appear on the app when pointed north and south after dark.

As well as a slick and simple design, complete with a cosmic calendar and a weather forecast, the Sky Guide app's 'featured' section contains a mix of excellent news and features by science communicator Dr Jenifer Millard (@DrJeniMillard on Twitter). The available upgrades increase the number of stars, objects, satellites and zoom power (as well as weather predictions and a dark-sky finder), but the free version – with 24 constellations, 100 deep-sky objects and ISS tracking – is likely to be enough for casual stargazers.

VERDICT

A slick and simple app with an excellent astronomy news and features section. The free version is a great option for casual stargazing.

FOR The basic version is free and visually impressive.
AGAINST Odd aurora effects are misleading.

OVERALL SCORE ★★★★☆

Stellarium PLUS

Price £11.99 • **OS minimum version requirement** iOS 12.0 • **Developer** Noctua Software • **www.**noctua-software.com/apps • **https:**//apps.apple.com/gb/app/stellarium-plus/id1458716890

Many amateur astronomers use the free and open source Stellarium planetarium software on their desktop computers, but the developer's lesser-known apps are just as impressive. A basic free version offers the usual augmented reality experience, with overlaid stars, constellations, planets, comets, satellites and deep-sky objects, while this step-up Stellarium PLUS version – a separate app that costs £11.99 – increases the database from 10th magnitude to 22nd magnitude stars.

Stellarium PLUS is aimed more at telescope owners: it can control a scope using Celestron NexStar, Orion SynScan and LX200 serial protocols and it even simulates what an object will look like through a specific telescope.

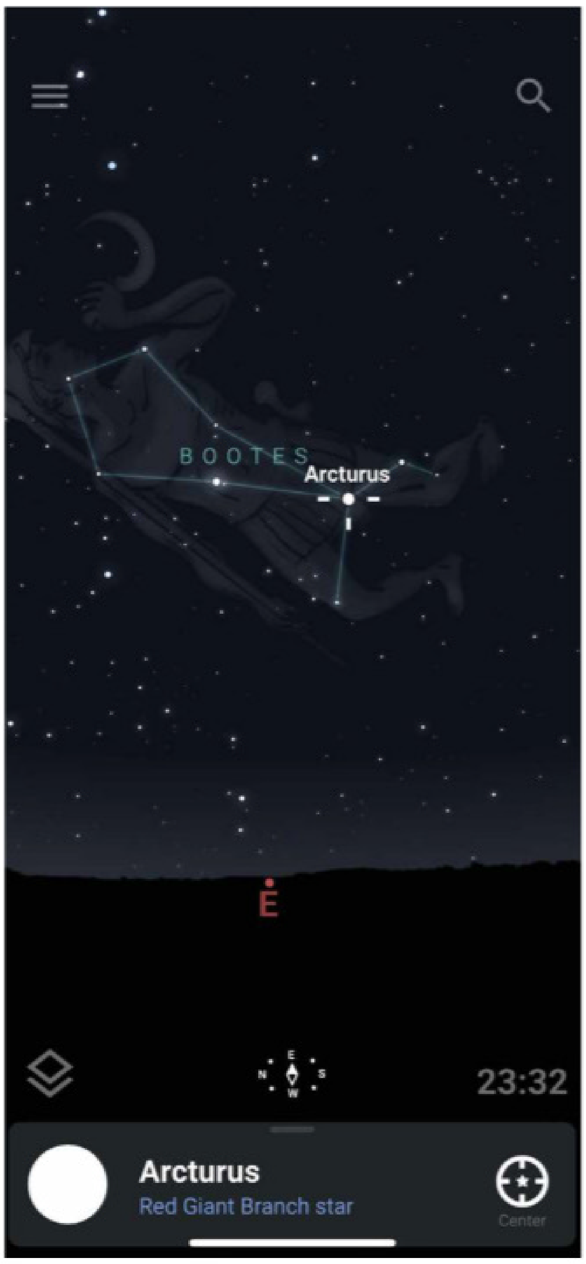
The expanded database of stars now includes the new Gaia DR2 catalogue of over 1.69 billion stars, as well as over 10,000 asteroids. As with the desktop version you can zoom in on detailed images of deep-sky objects, and simulate landscapes and Earth's atmosphere to show realistic sunrises, sunsets and atmospheric refraction. We also love Stellarium's representations of constellations and asterisms from non-Western cultures.

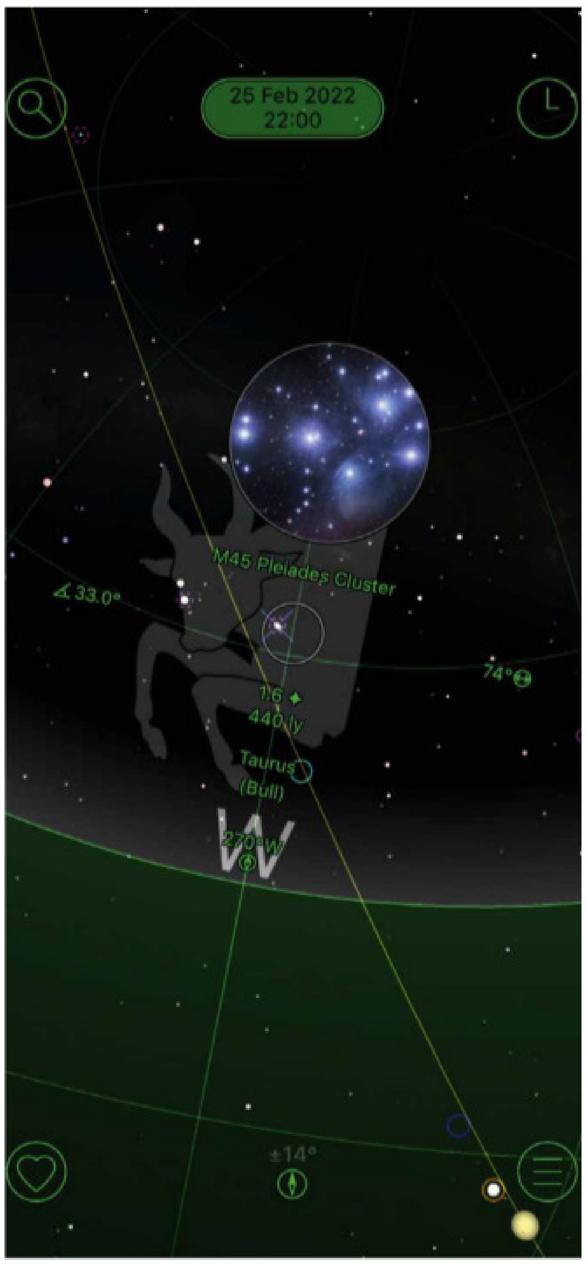
VERDICT

A familiar experience for users of the desktop version, Stellarium PLUS offers telescope control and a massive database down to 22nd magnitude stars.

FOR Polished, open-source software.
AGAINST Slightly reduced dataset when offline.

OVERALL SCORE ★★★★☆





GoSkyWatch Planetarium

Price £3.49 • **OS minimum version requirement** iOS 9.3 • **Developer** GoSoftWorks • **www.**gosoftworks.com/apps/goskywatch • **https:**//apps.apple.com/gb/app/goskywatch-planetarium/id284980812

With so many astronomy apps now either costing a lot of money or keeping a lot of features behind in-app purchases, it's great to see the stargazer-centric GoSkyWatch Planetarium still available for a low price.

It's got one of the best transitions from portrait to landscape: just swivel a smartphone and the night sky remains serenely still (most stargazing apps reset or refresh). It also has a unique touchless navigation system that makes everything incredibly simple. Instead of the user having to touch an object (and receiving reams of information), this app features a small target circle in the centre of the screen. As you move the phone, stars and planets – even those too dim to see unaided – naturally pass through that circle. As they do, up pops some simple information below the circle, including the name, constellation and how many lightyears away it is. If it's a planet, a small, image of it rotating briefly appears. Amusingly, it also has a 'Pluto is a planet' option. ▸

VERDICT

A uniquely touchless experience and a slick design make this one of the best apps for casual, naked-eye stargazers.

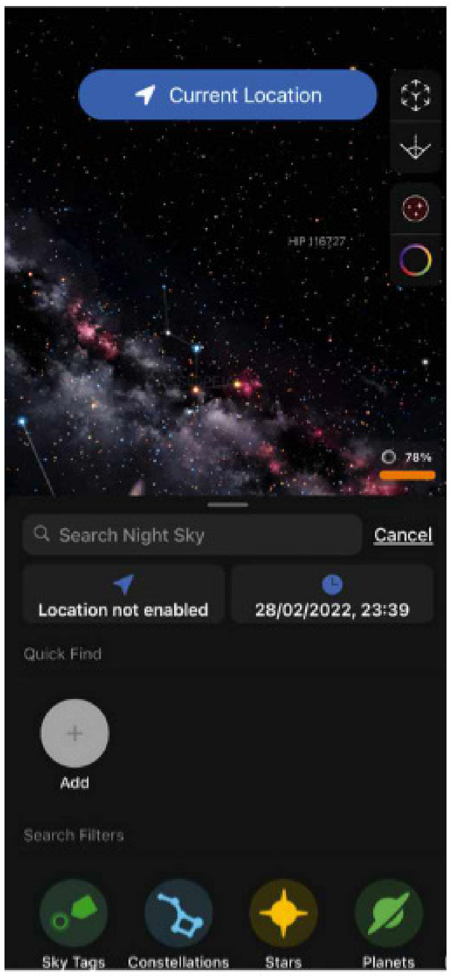
FOR Smooth portrait-to-landscape transitions and touchless navigation.
AGAINST There's no free option and it only includes stars that are visible to the naked eye.

OVERALL SCORE ★★★★★

6 OF THE BEST

Night Sky

Price Free; Premium £4.99 per month or £29.99 per year • **OS minimum version requirement** iOS 13.0 • **Developer** iCandi Apps • **www.**icandiapps.com/night-sky-4 • **https:**//apps.apple.com/gb/app/night-sky/id475772902



Why not share the night sky? The Night Sky app's 'connected stargazing' feature is a virtual shared stargazing session, allowing members a FaceTime Audio call between iPhones to add stars, planets, constellations and satellites to the session in real time. However, it's a feature that is only open to Night Sky Premium subscribers (£4.99 per month or £29.99 per year).

Fortunately, this is not the case with another new feature, 'Sky Tags', which is free to try out a couple of times: it allows objects in the sky to be saved for future reference and also shared via Apple's iMessage for others with the Night Sky app to find. As a bonus, you can attach observation notes and even your own astrophotography to each 'Sky Tag', which is a nice feature. Meanwhile, 'Sky Timestamps' lets you access the sky on specific dates, such as the dates of your next planned star party, but just as impressive is built-in data on local stargazing conditions and an auto-red light mode.

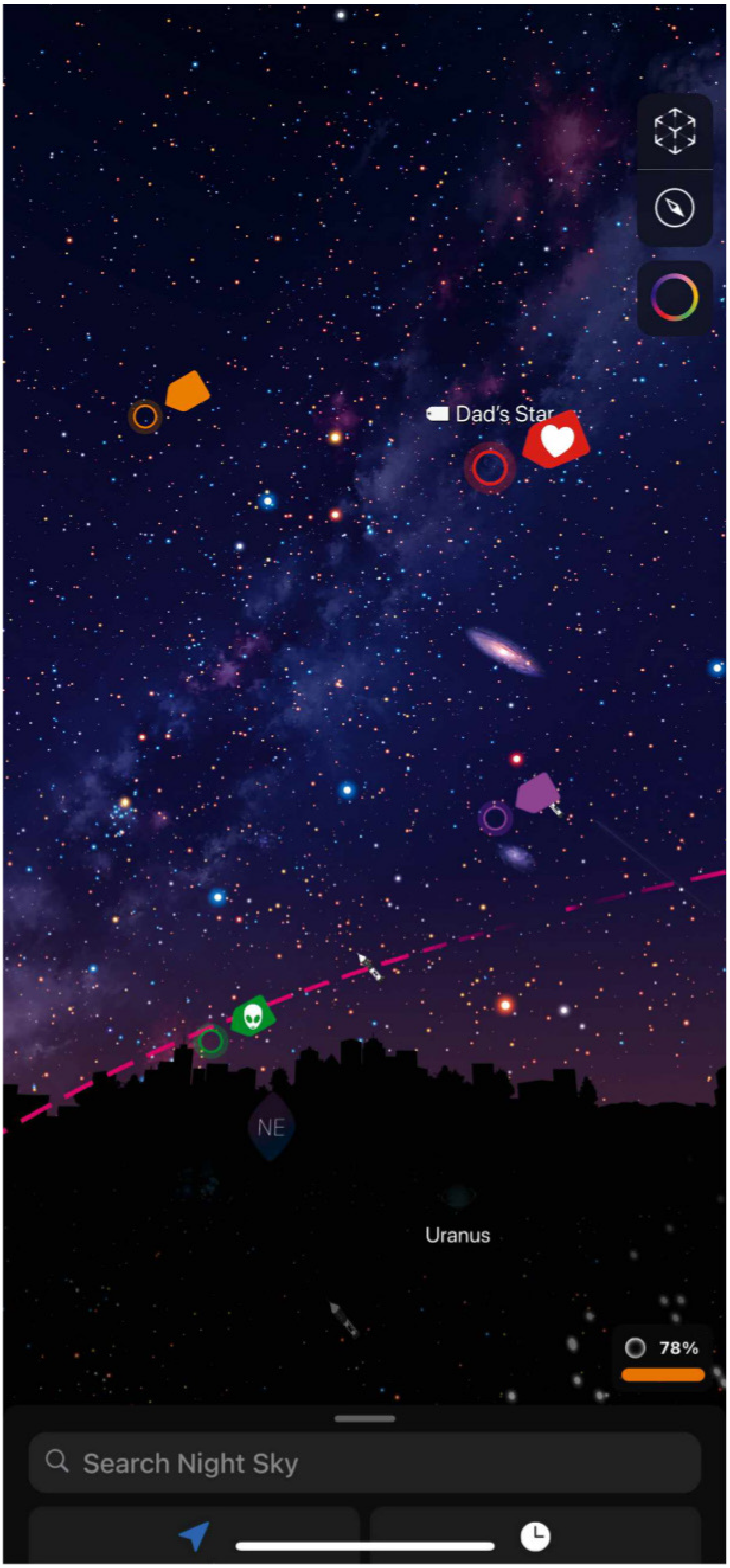
The free version is worth trying out, but the best features do require a subscription.

VERDICT

All-new sharing, virtual stargazing sessions and astrophotography upload, but only if you pay extra.

FOR **A clean interface and advanced features.**
AGAINST **The most useful features require a monthly or annual subscription.**

OVERALL SCORE ★★★★☆



Sky Tonight

Price Free; Premium access £0.79 per month or £4.99 per year • **OS minimum version requirement** iOS 11.0 • **Developer** Vito Technology • **www.**starwalk.space/en • **https:**//apps.apple.com/gb/app/sky-tonight-star-gazing-guide/id1570594940

When we are observing in the real world, trees and buildings often get in the way. Cue this well-designed new app's 'interactive trajectory' feature, which will show you the precise movement of a selected object, relative to where you are, for the rest of the night. It's a powerful addition that, when combined with the app's 'AR' (Augmented Reality) mode, will overlay the sky map on the surroundings using a smartphone's camera. Meanwhile, on the interactive map, the magnitude limit of what is displayed can be changed using a slider at the bottom of the screen, so it's obvious what you can see with the naked eye, binoculars and telescopes, respectively.

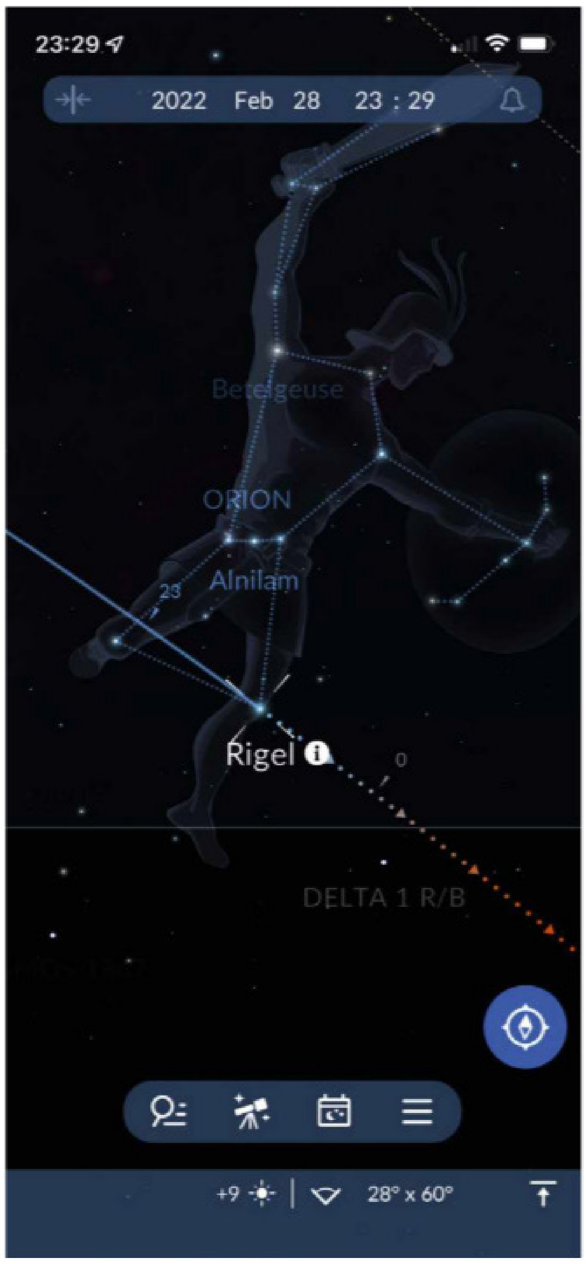
There's an easily searchable calendar that presents a list of celestial events that are coming up in the user's sky, complete with the best observation times, Moon phase and stargazing conditions. All the events can be saved to create an observing list, complete with notifications. This is an impressive free app, but the events are limited to a total of three unless you take out the small Premium subscription.

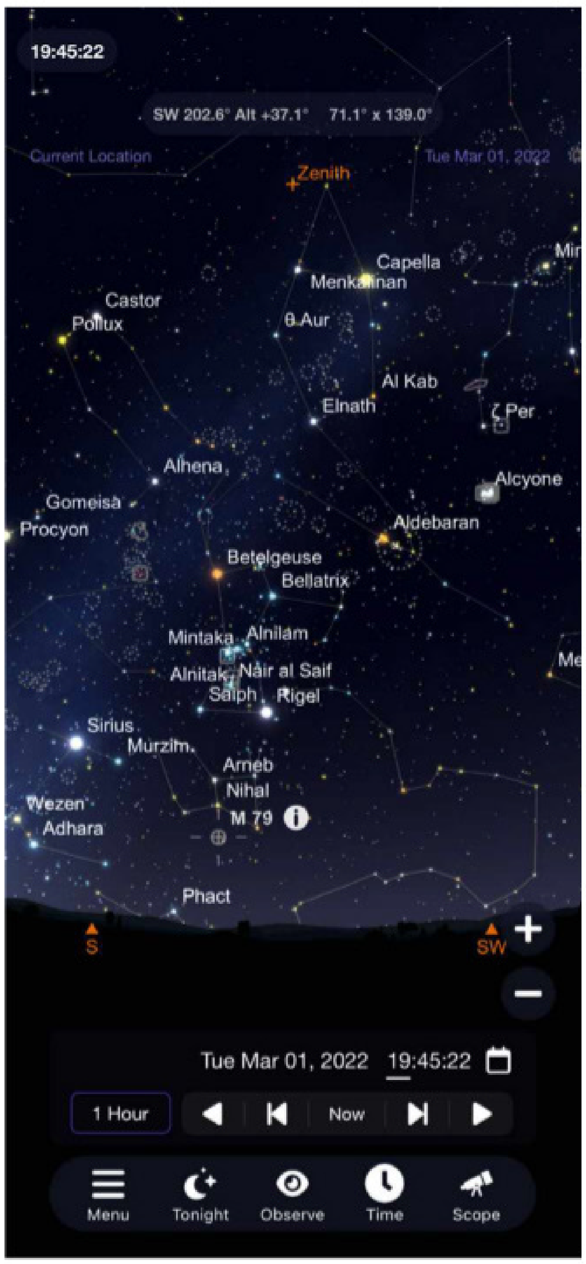
VERDICT

The app has impressive one-handed operation with uniquely practical features for stargazers and amateur astronomers.

FOR Useful real-world stargazing features.
AGAINST No telescope control features.

OVERALL SCORE ★★★★½





SkySafari 7 Plus & Pro

Price Plus £17.99, Pro £21.99 • **OS minimum version requirement** iOS 14.0 • **Developer** Simulation Curriculum Corp • **www.**skysafariastronomy.com • **https:**//apps.apple.com/gb/app/skysafari-7-plus/id1567654881

This app has been around for years in many guises and it keeps on improving. The very latest version comes in two distinct flavours, Plus and Pro, which cost £17.99 and £21.99 respectively. Please note that it's not possible to upgrade from one to the other.

So what are the differences? The Plus version shows 2.5 million stars and 32,000 deep-sky objects, while the Pro version reveals 100 million stars, three million galaxies down to 18th magnitude, and 750,000 Solar System objects. Crucially, both play nicely with Wi-Fi-controlled telescopes (via the ASCOM Alpaca and INDI protocols), which puts even the basic Plus version ahead of most other stargazing apps.

Other must-have features on both versions include a 'Sky Tonight' area, notifications, a logbook, a stargazing session planning zone and a red-light mode to help your night vision. You can share your observations with others (also using SkySafari) via SkyCast, but we can't quite see the point of 'OneSky', a mode that allows you to see what random other users are observing in real time.

VERDICT

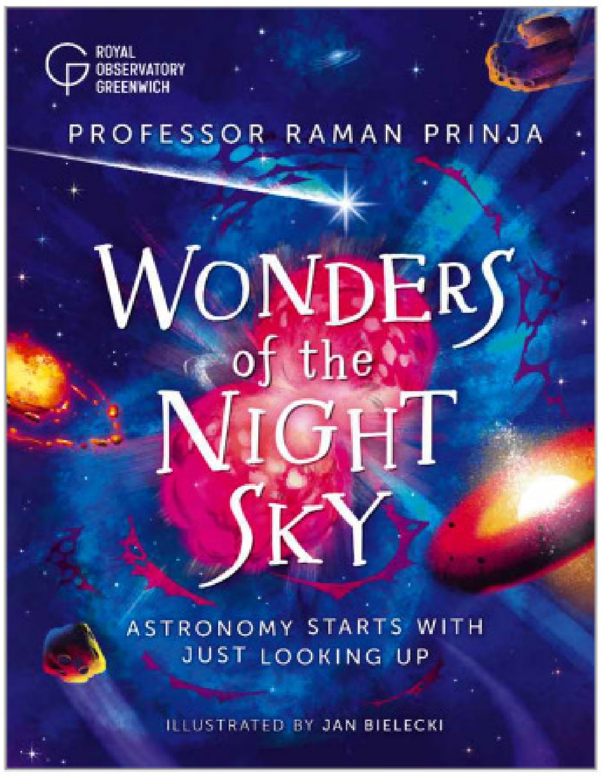
An expensive and impressive toolbox for amateur astronomers, although it takes time to get to know.

FOR Telescope control and hobbyist features.
AGAINST Using the app requires a steep learning curve, and it's expensive.

OVERALL SCORE ★★★★

New astronomy and space titles reviewed

BOOKS



Wonders of the Night Sky

Raman Prinja
Hachette Children's
£14.99 ● HB

Introducing children to astronomy can be a tricky undertaking. You want to engage them and give them enough information without getting too complicated. Then there is the question of equipment; not many parents can afford to splash out on an expensive telescope for a child whose initial interest may easily wane by the next week.

This book provides a basic introduction to the subject. It is brightly illustrated and packed with plenty of information to get you started. It doesn't ask for much in the way of kit: most objects can be seen with the naked eye or at most a pair of binoculars. It gives equal coverage to both the Northern and Southern Hemispheres, teaching about the lives of stars and how to recognise a few of the major constellations. It explores our Moon, its phases and eclipses, though it omits to mention solar eclipses or how to view them safely. The planets are discussed as well as asteroids, comets, meteor showers, aurorae, galaxies and human-made satellites.

There are fun activities to try out, such as creating your own Moon craters and a simple Sun–Earth–Moon orrery.

The text is concise though quite small for reading outside at night. Some terms, 'geostationary orbit', for instance, are missed out of the glossary and need some explanation. There is a helpful list of further reading books, useful websites, blogs and podcasts to explore, but although the text advises the use of apps on mobile devices to aid you when stargazing, none of these are included in the list.

As with many astronomy books, the illustrations do not represent what your eyes will see, even through binoculars. Most objects will be just points of light or faint smudges, and perhaps that fact could be stressed more in the text.

▲ A child's interest in the night sky can grow into a lifelong pursuit

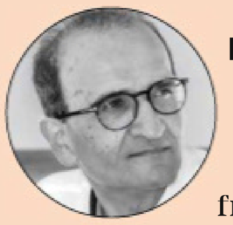
M-GUCCI/ISTOCK/GETTY IMAGES

I also found that some of the illustrations were a case of style over substance. The star positions in the constellations, for example, are overpowered by the drawings of the mythical figures and the Moon map could have had more detail.

Niggles and omissions aside, this book provides a good basic primer to the night sky for any young astronomer.
★★★☆☆

***Jenny Winder** is a freelance science writer, astronomer and broadcaster*

Interview with the author
Raman Prinja



How were you first inspired by the night sky?

I was starstruck from the moment I first gazed at a clear night sky, well away from the bright lights of London. The first constellation I learnt to spot was Orion, with its coloured stars and fabulous 'great hunter' Greek mythology. Making the connection between stars at night and the Sun as a star also fascinated me. My fascination deepened when my parents bought me my first telescope, at the age of 12.

What are your tips for getting young people into astronomy?

My top tip is to hold a family or group star party. Pointing out constellations and features of the Moon and planets is a great science adventure. Mix in some fascinating facts about the Universe. It's great to plan a night sky fun activity if you're on holiday in a location away from cities, where the darker night can be filled with stars.

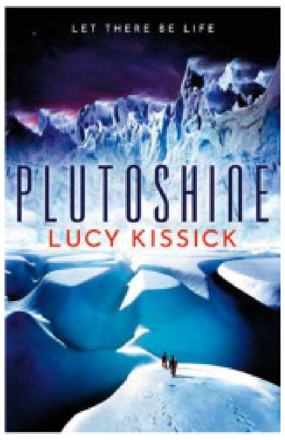
What opportunities await the next generation of astronomers?

They'll have some amazing telescopes to study the Universe. The James Webb Space Telescope (JWST), as well as new 30m-wide telescopes on Earth and radio telescopes, will provide incredible amounts of new data. We'll need to think up clever new methods, such as artificial intelligence, to study these enormous observations. But they'll also have the challenge of the increasing glow from artificial satellites and space junk orbiting Earth. This could become a problem as commercial companies are planning to launch 100,000 new satellites over the next decade.

***Raman Prinja** is professor of astrophysics at University College London*

Plutoshine

Lucy Kissick
Gollancz
£16.99 ● PB



Plutoshine tells the story of a future where humanity has at last spread beyond Earth and alien life has been discovered within our Solar System. But as scientists prepare to transform Pluto from a frozen world to a potential new Earth, a child holding unspeakable secrets could change humanity's understanding of the Universe forever.

Author Lucy Kissick's scientific background shines in this debut novel, telling a tale of terraforming, sabotage and friendship, centred upon a mute 10-year-old Plutonian, Nou.

Those interested in how humanity might be able to transform the Solar System's furthest reaches into habitable new worlds will enjoy the blend of science and story *Plutoshine* offers, but others may struggle with inconsistent pacing and wordy descriptions. In places the plot feels too rushed for relationships and character motivations to be fleshed out, while in others the focus on minute detail makes it difficult to grasp the bigger picture. The dialogue can be stilted, making it hard to empathise with the key characters, and unclear descriptions make it hard to visualise the world in which the book is set.

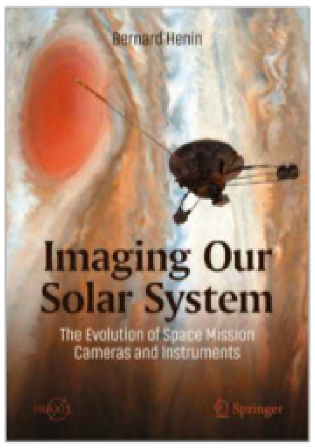
Despite this, Kissick makes use of a dual narrative to add intrigue and urgency. Fans of Andy Weir's *The Martian* will love the descriptions of the technicalities of terraforming a distant world, as will those who wonder what humanity's exploration of new lands might look like, or what life we may find lurking there. ★★★☆☆

***Katie Sawers** is a science writer specialising in physics and astronomy*

Imaging our Solar System

PACKED WITH PHOTOS

Bernard Henin
Springer Praxis Books
£24.99 ● PB



Of all the data returned by space missions, it's the images that immediately grab our attention. It seems that, as a species, we always wonder what lies over the horizon.

Along with over 100 images, including some of the most iconic pictures yet taken, in *Imaging our Solar System* the author takes us from the earliest flights to carry a camera aloft by balloon, through to the present and beyond.

As most space missions have included some form of imaging system, this book covers a lot of ground. It's divided into three parts: the early missions to image the Moon and fly by our nearest neighbours; through the digital revolution which brought the ability to really process and manipulate the raw data; to the current 'New Golden Era', which has seen impressive achievements from a growing number of countries. These now include China, Japan, India and the UAE. The most recent mission discussed is Chang'e 5, launched in November 2020.

There is a lot of information here, but it is always presented in a very readable way. The preface and appendices offer more basic information to those less familiar with imaging, as well as mission lists, further reading and a full index.

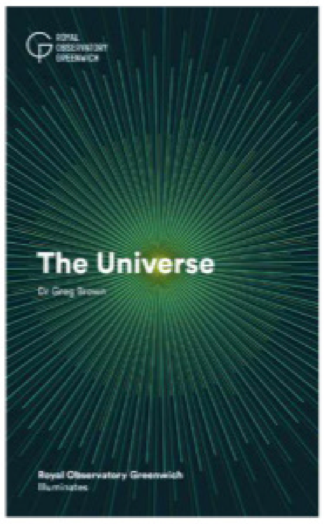
As we are so spoiled for choice, there will always be some disagreement about which images to include in such a book, but I found the balance between those of historic interest and pure eye candy about right.

It certainly maintains the excellent reputation built up by the Springer-Praxis Space Exploration book series. ★★★★☆

***Mark Bowyer** is an expert in the US crewed space programme*

The Universe

Greg Brown
National Maritime Museum
£9.99 ● PB



How did the Universe begin? How will it end? Is it infinite? And what do we know about the mysterious dark energy and dark matter that are thought to pervade the Universe? These questions, and many more, are dealt with at lightning pace in this new book, *The Universe*, by Dr Greg Brown, an astronomer working at the Royal Observatory Greenwich.

Without assuming any mathematical or detailed scientific knowledge, *The Universe* leads us from the basic observations that gave rise to the Big Bang theory, to our modern 'standard model' of cosmology. Dr Greg Brown allows us to pause along the way to consider, among other topics, inflation, primordial nucleosynthesis, the splitting of elemental forces, the epoch of recombination and the cosmological 'dark ages'. But the story is told with fluidity and speed, never allowing the reader to get bogged down in complexities and including only enough explanation to keep the journey going. We arrive at a discussion of the eventual fate – or possible fates – of the Universe. Always readable, the author has done a fine job of distilling the facts with a text that is both lucid and light-hearted.

The Universe is a short book that can be devoured in just a few hours. Written at a level for the absolutely uninitiated, it will find favour with amateur astronomers, but may ultimately prove unfulfilling to the more seasoned reader. Indeed, if you are just starting out on your quest to understand the intricacies of modern cosmology, this is a good place to start. Furthermore, it may just whet the appetite enough to propel you into the plethora of more detailed descriptions that are available. ★★★★☆

***Dr Alastair Gunn** is a radio astronomer at the Jodrell Bank Observatory*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Celestron NexYZ DX Smartphone Adapter Kit

Price £59.99 • **Supplier** Harrison Telescopes • **Tel** 01322 403407 • **www.harrisontelescopes.co.uk**

Take your first step in astro imaging with this adaptor that lets you use your smartphone afocally, through the eyepiece of your scope. It comes with a bluetooth shutter-release to help prevent vibrations when taking an image and works with 1.25-inch and 2-inch barrels.

2 StellaLyra 1.25-inch Eyepieces

Price £169 • **Supplier** First Light Optics • **www.firstlightoptics.com**

These eyepieces produce sharp, flat images with colour control across their 68° field of view, with a long eye relief for comfortable viewing. Available in focal lengths of 7mm, 9mm, 12mm, 14.5mm and 18mm.

3 ANTLIA Narrowband 4.5nm OIII EDGE 1.25-inch Filter

Price £191 • **Supplier** 365 Astronomy • **Tel** 020 3384 5187 • **www.365astronomy.com**

With an 85 per cent light transmittance across the 500.7nm line – higher than many other narrowband filters – this OIII (Oxygen) filter allows you to pick out the faint details in nebulae structures. SII (Silicon) and Ha (Hydrogen-alpha) filters are also available.

4 Starizona Nexus 2-inch Reducer/Coma Corrector

Price £499 • **Supplier** The Widescreen Centre • **Tel** 01353 776199 • **www.widescreen-centre.co.uk**

ADVANCED This coma corrector will ensure that your Newtonian telescope functions at its best when photographing the cosmos. The reducer decreases the focal length by 0.75x to give a large field of view and reduce exposure times.

5 Planet Map Sweatshirt

Price £40 • **Supplier** Science Museum • **https://shop.sciencemuseum.org.uk**

Show your love for the bodies of the Solar System with this jumper. It's inspired by the iconic London Underground map and is packed with statistics.

6 Planet Coasters

Price £13.85 • **Supplier** The Little Green Bag • **www.thelittlegreenbag.co.uk**

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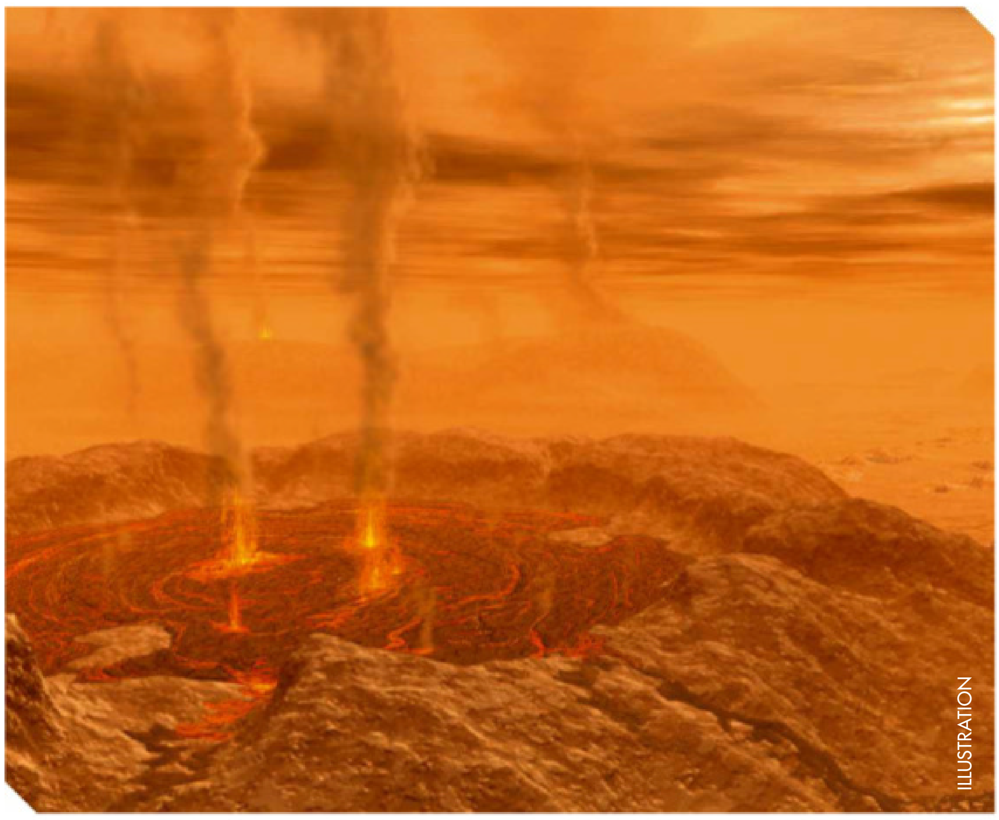
Melissa Brobby interviews Martin Turbet

Q&A WITH A PLANETARY RESEARCH SCIENTIST

Research into whether Venus had liquid oceans in its past is giving more insight into how Earth has so far avoided a runaway greenhouse effect

Considering how molten Venus's surface was in its past, how might it have formed a liquid water ocean?
When we think about the evolution of planets, we envision them beginning their life in a hot and molten state, and as they evolve through time, they emit radiation into space and cool down. So, the key question is whether or not by cooling down, Venus was able to condense the water it had in its atmosphere onto the surface. If the water did not condense, then it is unlikely that liquid water oceans would have formed. The current thinking is liquid water oceans might have formed from steam at an early point during Venus's evolution, the steam condensing on the planet's surface and turning from a vapour to a liquid. This is probably what also happened on Earth in its past.



▲ The only thing that could flow on Venus today is lava, but did the planet have oceans in the distant past?

CHRIS BUTLER/SCIENCE PHOTO LIBRARY

What methods were used to find this out?
I have been using a Three-Dimensional Global Climate Model designed to represent all the dimensions of a planet, and the physical processes that are at play in planetary atmospheres. We simulated the way the gas and clouds interact with light coming from the Sun, and the way the water vapour in particular will condense and evaporate from clouds. We also simulated the way the atmosphere circulates. All these equations are combined in the same model to represent in the best way possible how an atmosphere will behave. This type of model is similar to the one that colleagues in my research group have been using to evaluate global warming on Earth.

According to your simulations how long would these oceans have existed on Venus and when would they have begun to disappear?
The simulations give an atmosphere that is cloudless in regions on Venus where the Sun reaches the zenith; clouds are formed mainly at the poles and on the night side of the planet. This peculiar distribution of clouds would produce strong heating by the greenhouse effect, preventing liquid water from forming on Venus's surface, which is likely to have been the case since the early stages of the planet's development.

Martin Turbet is a CNRS research scientist at the University of Geneva

What could the study of Venus's history tell us about climate change happening on Earth and what the future could hold for our planet?
If at some point Earth gets warm enough, it will trigger a runaway greenhouse effect, which will result in oceans evaporating from the surface and into the atmosphere, and this may be irreversible. However, this would happen over a long period of time during Earth's evolution.

What prevented Earth from suffering the same fate as Venus in its earlier years?
What we've found is that Earth's insolation – the amount of solar radiation a planet receives on its surface – was probably the key, and maybe the reason for why it escaped a similar fate. This was how it was able to condense its oceans in the first place. The only way water could condense on Earth's surface would be to decrease the amount of solar radiation that the planet received. On Earth, four billion years ago, this was sufficiently low because the luminosity of the Sun was lower in the past, which is known as the 'faint young Sun paradox'. What we are seeing from our simulation results is that this is a key element to consider in the evolution of Earth, and how immensely important this part of the planet's history is.

Are there plans to apply this model to any future exoplanet missions?
A mission we may see in the coming years will give us the opportunity to probe exoplanets with steam atmospheres, and use those planets to better understand what lies beneath, and ask how their clouds are forming. The best telescope we may have for answering these questions is the James Webb Space Telescope (JWST).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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch the peak of the Eta Aquariids, and enjoy a month of morning planetary encounters

When to use this chart

1 May at 00:00 AEST (14:00 UT)
15 May at 23:00 AEST (13:00 UT)
31 May at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MAY HIGHLIGHTS

The Eta Aquariid meteor shower can be impressive with meteors that are fast, yellow and have persistent trains. Active from 19 April to 28 May, the peak is on the night of the 6th and morning of the 7th. The shower is best seen in the predawn when the radiant is near maximum height and the sky is Moon-free. The radiant is where the shower appears to originate on the sky, in this case near the star Eta (η) Aquarii. At its peak, look in the general direction of Mars.

STARS AND CONSTELLATIONS

The southern Milky Way is brilliantly displayed in May's evening skies. If you face due south, its most southerly portion rides high, crossing the meridian. Visually, this region lies around Musca, the Fly. The galactic equator passes close to Alpha (α) Centauri and Acrux (Alpha (α) Crucis). The central hub of the Milky Way is rising in the east, marked by Sagittarius's Teapot standing on its handle. The view of our Galaxy stretches across the sky and flows into the western horizon.

THE PLANETS

Mornings present a feast of planets in May. Saturn is rising around midnight and transiting around dawn. To see Mars, Neptune, Jupiter and Venus at their best in the eastern sky, the predawn is a magic time. May opens with a view of Jupiter and Venus only 0.2° apart! Mars has close conjunctions with Neptune on the 18th (0.7° apart), followed by a meeting with Jupiter separated by less than 1° for May's last three days. Uranus and Mercury reappear low at dawn at the month's end.

DEEP-SKY OBJECTS

This month we visit Virgo. Theta (θ) Virginis (RA 13h 09.9m, dec. –5° 32') is an excellent double star for small scopes with a bright, white primary (mag. +4.4) and a fainter yellow companion (mag. +9.5), separated by 7 arcseconds.

The third magnitude star, Epsilon (ε) Virginis, is a gateway to the Virgo/Coma Cluster of galaxies. Moving 2.5° westwards from the star finds the first impressive eyepiece field of view, showing a pair of great (10th magnitude) galaxies! Although both are barred spirals their orientations are different. NGC 4762 (RA 12h 52.9m, dec. +11° 14') is edge-on, giving a needle-like appearance (5 arcminutes x 0.5 arcminutes), with a central bulge and a star-like nucleus. Only 11 arcminutes northwest lies NGC 4754, which is more face-on and shows an oval-shaped (3 arcminutes x 2 arcminutes) faint halo.

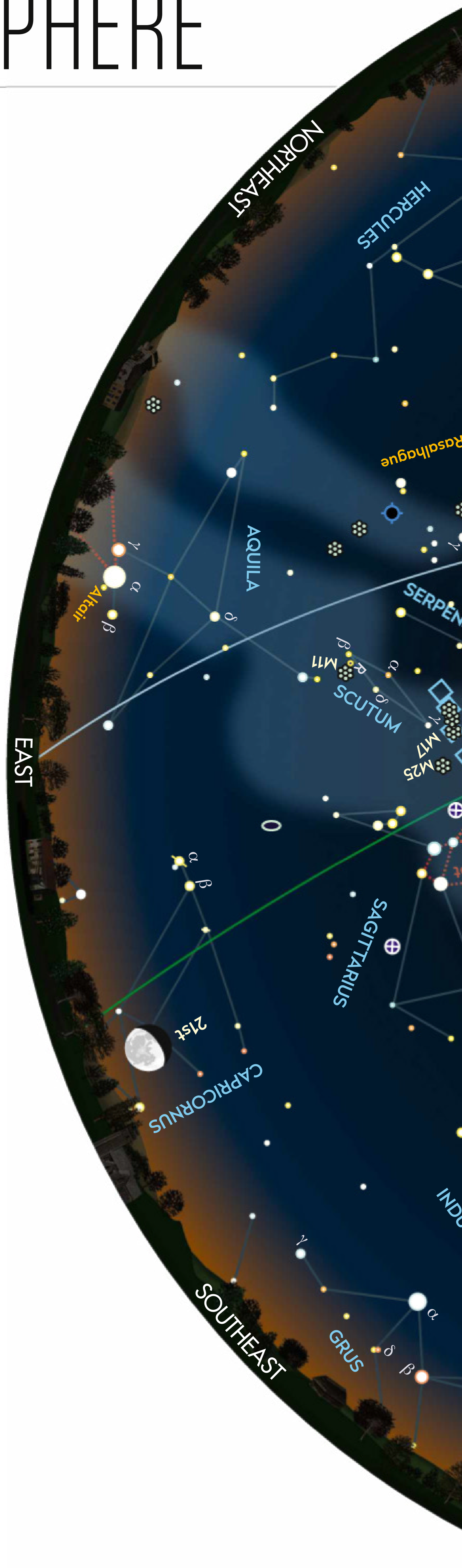

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
M92
M106
M51
CANES VENATICI
M63
M94
Cor Caroli
BOÖTES
Kite
Keystone
M13
CORONA BOREALIS
R
COMA BERENICES
NGC 4565
URSA MAJOR
M3
Arcturus
Rasalgethi
M64
Diadem
M53
LEO
Sickle
NGC 4762
M60
M87
M86
M59
9th
OPHIUCHUS
SERPENS CAPUT
M5
VIRGO
NGC 4754
M99
Leo Triplet
12th
Regulus
Celestial Equator
M12
M10
SERPENS CAUDA
15th
Spica
M104
Ecliptic
LIBRA
CORVUS
CRATER
HYDRA
Alphard
M16
M23
M20
M80
Antares
M4
M83
CENTAURUS
18th
M6
SCORPIUS
LUPUS
Ghost of Jupiter
Teapot
M7
NORMA
ω Cen
ANTLIA
CRUX
CIRCINUS
Jewel Box
Coal Sack
NGC 3699
VELA
PYXIS
PUPPIS
CORONA AUSTRALIS
TELESCOPIUM
ARA
TRIANGULUM AUSTRALE
MUSCA
"Peacock Star"
APUS
CHAMAELEON
CARINA
False Cross
PAVO
OCTANS
South Celestial Pole
VOLANS
SMC
Tarantula Neb
47 Tuc
HYDRUS
MENSA
LMC
PICTOR
DORADO
Canopus
TUCANA
RETICULUM
Achernar